


# Vessels of Concern Risk Assessment Methodology

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## Executive Summary

The Government of Canada has recognized that wrecked, abandoned and dilapidated vessels (vessels of concern or VOC) pose hazards to the environment, public health and safety, and local economies. In 2016 the Government of Canada developed a **“National Strategy to Address Wrecked and Abandoned Vessels”** (the National Strategy) to reduce abandonment of vessels and manage the risk posed by the existing vessels.

In order to manage the risks posed by vessels of concern, a **“Risk-Based Strategy to Address Vessels of Concern”** was developed by the Canadian Coast Guard. Part of this broad measure includes the development of an inventory to understand the extent of the issue nationally, and the development of a risk assessment methodology (RAM) that can be used to objectively assess the risks posed by hazardous VOC when compared to other vessels in the national inventory.

In addition, the risk assessment approach needs to provide a methodology that is easy to follow, intuitive and that, as far as is practical, will achieve consistent results across all regions of Canada.

The RAM is based on two main factors: **Impact** and **Probability**. **Impact factors** indicate the potential level of risk a vessel poses; it can also be expressed as the ‘severity/impact’ axis in a risk matrix. In developing the RAM, four risk categories have been considered: Environment, Economy, Public Safety and Socio/Cultural Impacts (including Indigenous). **Probability factors** are the likelihood that hazard factors can materialize and can be expressed as the ‘probability’ axis in a risk matrix. These factors describe the probability that the condition of the vessel can degrade or that external conditions can impact the vessel, and therefore increase the likelihood of a hazard materializing in one of the risk categories identified above and the timeframe it would likely materialize within. The following four general categories have been considered: the effects of the environment on the vessel; the physical state of the vessel; what pollutants are onboard the vessel; and, vessel information / history.

As far as is practical, the methodology consists of objective questions with yes/no responses and is split into a number of phases as follows:

- **Phase 1** – Initial reporting and entering of data about the VOC such as vessel identifiers, position, status of the vessel such as moored, anchored, grounded etc. (if known)
- **Phase 2** – A physical attendance to the site of the VOC to complete an initial risk assessment. It is expected that this phase will most likely be conducted by Coast Guard VOC officers. Depending on the vessel type, its physical state and its location, it may not be possible to collect some of the required information. If necessary, the missing information will be addressed in the subsequent phases. An initial **“Risk Score”** will be calculated for the vessel. It is envisaged that, for the majority of the VOCs, the completion of Phase 2 will be sufficient to provide an accurate assessment of the risks posed by the vessel.

- **Phase 3** – A Technical Risk Assessment of the vessel and its condition to refine the probability factors. Where necessary, this will include assessment of the vessels structure, moorings, type and quantity of pollutants onboard. It will also provide information on likely changes in the vessel in the short and long term. Some of the necessary information may require calculations and / or specialist technical knowledge, and therefore, it is likely that this phase will be conducted by third party marine consultants. This phase is designed to build on Phase 2 and will provide definitive responses to those questions that produced an “unknown” response, as well as additional questions, to further define the risk that the vessel poses. Following the completion of this phase the initial risk score obtained after Phase 2 will be modified.
- **Phase 4** – A Comprehensive Risk Assessment to further assess the potential impact the VOC could have on the environment, local economy, public safety and socio-cultural receptors. This phase is designed to build and expand upon the information collected in Phase 2 by providing definitive answers to those questions that returned “Unknowns” during Phase 2 as well as further refining the impact potential posed by the VOC. This phase should not require specialist knowledge but rather draw upon information from various relevant sources and may be completed by the VOC team or a contractor. Following the completion of this phase the risk score obtained after Phase 2 and/or Phase 3 will be modified.
- **Phase 5** – A re-evaluation of the risk score following remedial works. This phase is designed to allow modification of the risk score to reflect work that may include removal of pollutants; additional moorings; repair works to the structure; increased security to prevent public access; etc.

If, subsequent to the completion of the risk assessment, a VOC is re-attended for whatever reason, the RAM includes the ability to record basic metrics for the vessel for each visit. This will allow any changes in the vessel's condition to be identified. The RAM will take these into account and modify the risk score.

A risk score will be generated for each phase of the RAM, excluding Phase 1, by calculating a score for the impact and probability factors. The impact and the probability factors will be combined together and modified by an importance factor. The Importance factor allows the methodology to assign differential weighting to each of the impact and probability factors.

As well as an overall score the RAM will provide a breakdown as to which of the impact and probability factors are influencing the overall score. In this way it will be possible for potential mitigation measures to be identified.

It is understood that, particularly after completing Phase 2 - Initial Risk Assessment, that there may still be a number of unknowns that will require the completion of Phase 3 and/or Phase 4 to provide the necessary information. So, in addition to generating a risk score for the VOC, the RAM will provide a range risk score which will show what the possible maximum and minimum scores would be based on worst-case and best-case for all the unknowns identified during the completed phases.

It should be noted that Phase 3 and Phase 4 are stand alone, Phase 3 does not have to be completed before Phase 4; either or both of them can be omitted as required. By careful consideration of the confidence factors it is expected that, following the completion of Phase 2, no further assessment will be required for a large number of the VOCs. For those that do require further assessment, Phase 3 or Phase 4 will be conducted.

The purpose of the Risk Assessment Scoring Tool (RAST) is to allow VOC officers to assess VOCs in the field, store the results in a database, and analyze the current state of VOCs. The tool is a flexible, robust and versatile data management system enabling an assessor to complete an assessment of a Vessel of Concern (VOC), report the results back to the VOC inventory database, and allow decision makers to analyze the results. GIS tools managed through *ArcGIS Online* have been selected to assess the vessel; process the risk score; store the data in a database; and, analyze and report on the current state of VOCs. The Risk Assessment Tool has two main components, with each component developed to provide the necessary information to the Coast Guard for managing the VOC program.

The two components are as follows:

1. Risk Assessment Scoring Tool (RAST): A method to assess the potential risk associated with each VOC
2. Risk Mitigation Tool (RMT): A method to understand and evaluate potential risk mitigation options

The RAST and RMT will be separate components of the Risk Assessment Tool but will rely upon the same underlying technology allowing for a seamless transition of information through the assessment, analysis, and mitigation stages of VOC management.

The RAST will assist the Coast Guard with the scoring, managing and reporting on VOCs within Canada. In addition to scoring VOCs using the RAST a Risk Mitigation Tool (RMT) has been developed. The RMT provides the opportunity to manage the risk posed by the vessels to assess how various mitigation options can reduce the overall risk of a particular vessel.

To test the overall methodology and the functionality of the tool a number of test vessels have been assessed. The results of these test cases are detailed in a separate document titled "**RAM Validation Plan & Test Vessel Results**", document reference, **LOC/027/014742/VP/1.0**.

To facilitate the use of the tool a user manual has been developed. The manual provides an overview of the tool as well as details for use of the tool to complete the various phases of the assessment of a VOC. The manual also covers the use of the RMT.

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# List of Acronyms & Abbreviations

CCG	Canadian Coast Guard
DFO	Fisheries and Oceans Canada
ER	Environmental Response
HNS	Hazardous & Noxious Substance
HHERA	Human Health and Ecological Risk Assessment
IMO	International Maritime Organization
IRAS	Initial Risk Assessment Score
OPP	Ocean Protection Plan
PSPC	Public Services and Procurement Canada
RAM	Risk Assessment Methodology
SHC	Small Craft Harbour
TRAS	Technical Risk Assessment Score
UXO	Unexploded Ordnance
VOC	Vessel(s) of Concern
WAHVA	Wrecked Abandoned Hazardous Vessels Act



## Risk Assessment Methodology

# 1 Introduction

## 1.1 Background and Context

The Government of Canada recognizes that wrecked, abandoned and dilapidated vessels (vessels of concern or VOC) can pose hazards to the environment, public health and safety, and local economies. In 2016 the Government of Canada launched a national \$1.5 billion Oceans Protection Plan (OPP) with the goal to improve marine safety and shipping, protect Canada's marine environment, and help advance Indigenous reconciliation. A key component of the OPP, is the development of a "National Strategy on Wrecked and Abandoned Vessels" (the National Strategy) to reduce abandonment of vessels and manage the risk posed by the existing wrecks.

The National Strategy includes several measures to address irresponsible vessel management, hold owners liable and responsible and provide proactive federal authorities on hazardous vessels. These measures include:

- Introduction of the proposed *Wrecked, Abandoned or Hazardous Vessel Act* in the House of Commons
- National inventory and risk-based assessments of vessels of concern
- Improving vessel owner identification
- Establishment of long-term owner-financed funds for vessel remediation
- Vessel removals and disposal through two short-term funding programs:
  - **Abandoned Boats Program** that will provide approximately \$6.85 million over five years to assist communities in the assessment, removal and disposal of abandoned and wrecked small boats, educate boat owners on proper disposal of their boats and examine environmentally sustainable ways to build and dispose of boats.
  - **Small Craft Harbours Abandoned and Wrecked Vessel Removal Program** which provides approximately \$1.325 million over five years to harbour authorities and other eligible recipients to remove and dispose of abandoned and wrecked vessels located in DFO owned small craft harbours.

In order to manage the risks posed by vessels of concern, a "**Risk-Based Strategy to Address Vessels of Concern**" was developed by the Coast Guard. Part of this broad measure includes the development of an inventory to understand the extent of the issue nationally and development of a Risk Assessment Methodology (RAM) that can be used to objectively assess the risks posed by hazardous VOC when compared to other vessels in the national inventory.

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### 1.2 Objectives

The objective of this project is to develop a RAM that can be used across Canada to provide a consistent and efficient method to assess the risk posed by a VOC. The RAM must assess the level of risk posed by the VOC to the local environment, economy, public safety and socio-cultural impacts, including impacts to Indigenous Communities.

### 1.3 What is a Vessel of Concern

For the purpose of the RAM, a VOC is defined in accordance with the *Wrecked, Abandoned or Hazardous Vessels Act* and includes dilapidated, wrecked, abandoned and hazardous vessels. Application definitions to aid in the understanding of a VOC are detailed below.

A **dilapidated vessel** according to the Act means a vessel that meets any prescribed criteria and

- a. is significantly degraded or dismantled; or
- b. is incapable of being used for safe navigation

A **wreck** means

- a. a vessel, or part of a vessel, that is sunk, partially sunk, adrift, stranded or grounded, including on the shore; or
- b. equipment, stores, cargo or any other thing that is or was onboard a vessel that is sunk, partially sunk, adrift, stranded or grounded, including on the shore

An **abandoned vessel** is

- a. a vessel that an owner has left unattended for a period of two years

### 1.4 Guiding Principles

The RAM was developed to classify the VOCs already identified by the Coast Guard, as well as new potential VOCs, with the goal of prioritizing which VOCs require remedial action, removal and/or additional assessment.

It is intended that the RAM be a sequential approach with the ability to classify both existing and new VOCs, assess if a vessel is adequately risk managed, and to recommend if additional actions/assessments are required.

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### 1.5 Legislation concerning VOI

The *Wrecked, Abandoned or Hazardous Vessels Act* promotes the protection of the public, of the environment, including coastlines and shorelines, and of infrastructure by regulating abandoned or hazardous vessels and wrecks in Canadian waters and, in certain cases, Canada exclusive economic zone, and by recognizing the responsibility and liability of owners for their vessels. The Act was passed by the Senate as of December 2018 and was given Royal Assent as of February 2019.

The Act implements the *Nairobi International Convention on the Removal of Wrecks, 2007*, and, among additional items, the Act prohibits leaving dilapidated vessels in the same place for more than 60 consecutive days without authorizations and prohibits vessel abandonment. In addition, the Act authorizes the Minister of Fisheries, Oceans and the Coast Guard to take measures to prevent, mitigate or eliminate hazards posed by vessels of concern and to hold the owner responsible and liable for all costs incurred. Generally, the Coast Guard is the responsible authority for marine vessel oil and hazardous materials spills.

The authorities granted to the Coast Guard under the Act are complementary to Coast Guard's pollution prevent and response authorities under the Canada Shipping Act 2001. Furthermore, the Act maintains and builds on regulatory powers previously contained in the Canada Shipping Act 2001 related to the protection and preservation of wrecks having heritage value including ocean war graves.

The ability of mariners and boaters to navigate Canada's waters is protected by the federal Navigation Protection Act administered by Transport Canada. Vessels left anchored, moored or adrift in Scheduled Waters obstructing navigation may be ordered by the Minister to secure it or move it.

It is recommended that individuals potentially taking possession of a damaged, sunk or grounded vessel or wreck contact the Navigation Protection Program for advice on how to proceed. In situations where the owner of a wreck is not known, a Transport Canada official (within the Navigation Protection Program) called the Receiver of Wreck has designation to act as the custodian. Their responsibility is to determine the owner(s) of the wreck and return it, or to dispose of it. Transport Canada is required to give the registered owner 30 days' notice prior to authorizing any person to remove an abandoned, grounded, or sunk vessel.

It should also be noted that British Columbia has its own provincial legislation and the BC Ministry of Environment is the responsible authority for spills from structures. Generally, the province of BC has the authority to remove or destroy structures that are in trespass on its land. Where a vessel or structure is a person's sole residence additional considerations may be required to ensure seizure is not contrary to the Canadian *Charter of Rights and Freedoms*. In British Columbia, Transport Canada officials will not take action on vessels anchored or moored in waters covering Provincial Aquatic Land unless it is interfering with navigation. Provincial and local governments have reduced powers to address vessels as

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compared to structures. Provincial actions cannot unreasonably impede the public right of anchorage and the right of navigation, and federal laws may take precedence in trespass situations.

## Risk Assessment Methodology

# 2 Overview of Risk Assessment Methodology

## 2.1 Principals of Risk Management

Organizations of all types face internal and external factors that make it uncertain how they will achieve their objectives. Managing uncertainty in decision-making relies upon identifying, quantifying and analyzing those factors. More specifically, the RAM seeks to identify and evaluate the hazards (uncertainties) posed by VOC to allow the uncertainties to be characterized and integrated into a long-term plan to manage these VOC.

There are two aspects that will be used in the RAM to determine risk: the probability that a hazard could happen; and, the impacts (consequences) if that hazard is realized. A hazard is an event that could result in harmful impacts to the environment, infrastructure, human health and the economy. A more detailed definition of hazard is provided in **Appendix A**. In this context, "risk" is defined for the RAM as the probability and impact posed by vessels of concern.

The overall goal of a risk-based decision-making process is that both the probability and impact are equally taken into consideration. It provides an objective method to evaluate the risk the VOC poses and what additional actions may need to be taken. One of the fundamental principles of risk is that less severe consequences happen more often. For example, in the case of oil spills most people focus on the "if": how bad could the oil spill be "if" the vessel had a complete loss? They fail to take into consideration that the probability of a complete loss is very low. Whereas, smaller oil spills happen much more frequently and could therefore be considered a higher risk to the environment. In the VOC context, this could translate to targeting and remediating vessels that pose a higher risk instead of vessels which are more high profile but do not pose a significant risk in their current state.

The objective of the RAM is to develop a methodology that can be used to assess the risk posed by VOCs in Canadian waters. The approach used to assess the risk posed by VOCs is a qualitative approach, meaning that the RAM uses the professional judgement of the RAM user and others to assess the risk. Another risk assessment approach is to conduct a quantitative analysis where one generates probabilities and impacts based on statistical information collected. In order to develop and conduct a quantitative risk assessment detailed historical statistical information is required which is not available on VOCs in Canada. Therefore, a qualitative approach was taken which will allow for the determination of what level of risk individual VOC's pose from Very Low Risk to Very High Risk. What constitutes a Very Low Risk through to a Very High Risk is defined in **Section 5.0**.

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### 2.2 Review of VOC RAM from Other Jurisdictions

A literature review was conducted to gain an understanding of what is currently done in other jurisdictions to assess and manage VOCs. The results of the literature review are summarized in **Appendix B**. Best practices gleaned from the literature review are incorporated within the RAM.

### 2.3 Key Assumptions, Limitations and Application

To facilitate the understanding of the RAM, it is important to present the key assumptions and limitations of the RAM. The key assumptions and limitations of the RAM are as follows:

- The methodology will not determine whether or not a vessel is a VOC. It is assumed that a vessel will be designated as such prior to the assessment process being initiated
- The RAM can be used to assess VOCs in Canadian waters, it was not designed to assess vessels outside of Canada
- The RAM will only address the five phases identified in scope of work
- The RAM is not intended to determine the level of effort required to remediate the VOC, only the level of risk the VOC may pose
- The Risk Score is dependent on the quality of information input into the RAM
- Parts of the RAM are designed to be used by professional experienced naval architects or similar professionals

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### 3 Risk Assessment Approach

The risk assessment approach provides a methodology that is easy to follow, intuitive and could be completed by the assessor. This section lays the groundwork for the RAM that will be explained and expanded upon in subsequent sections. The RAM is based on two main factors: Impact and Probability. Both of these factors are explained in this section along with impact and probability factors that are included in this methodology.

#### 3.1 Assessor

For the purposes of this RAM, the assessor is defined as the person who is carrying out the assessment of a VOC. This person could be an employee of the Coast Guard (VOC Officer), employee of another government agency/department or a contractor/consultant hired by the Government of Canada to undertake the assessment.

#### 3.2 Impact Factors

Impact factors indicate the potential level of risk a vessel poses and can also be expressed as the 'severity/impact' axis in a risk matrix. An impact factor represents a threat to one of the four Risk Categories: Environment, Economy, Public Safety and Socio/Cultural Impacts (including Indigenous). The impact factors listed in the **Table 1** below are assessed through questions, depending upon the factor, in Phases 2 and 4.



## Risk Assessment Methodology

### Impact Factors

Categories	Factors
<b>Environmental</b>	<ul style="list-style-type: none"> <li>• Marine Protected Areas</li> <li>• Oceans Act areas of interest</li> <li>• Ecologically and biologically-significant areas</li> <li>• Species at risk critical habitat areas</li> <li>• Rivers under tidal influence</li> <li>• Important ecological areas (national wildlife areas, ecological reserves, protected natural areas)</li> <li>• Migratory bird sanctuaries or important bird areas</li> <li>• Migration or spawning areas</li> <li>• Sensitive shoreline or seafloor</li> <li>• Invasive species</li> <li>• Nesting or nursery habitat</li> </ul>
<b>Economic</b>	<ul style="list-style-type: none"> <li>• Commercial fisheries</li> <li>• Aquaculture activities</li> <li>• Shellfish harvesting</li> <li>• Tourism activities</li> <li>• Port authorities or small craft harbours</li> <li>• Private lands</li> <li>• Tourism potential of vessel</li> <li>• Population density</li> <li>• Sub-sea infrastructure (pipelines, sub-sea cables)</li> <li>• Public waterfront</li> <li>• Marine infrastructure (marinas, slipways, boat launches)</li> <li>• Parks (national, provincial, municipal)</li> <li>• Registered historic sites</li> <li>• Wharfage fee delinquency</li> </ul>
<b>Public Safety</b>	<ul style="list-style-type: none"> <li>• Accessibility by public</li> <li>• Navigational hazard</li> <li>• Criminal activity</li> <li>• Water resource extraction</li> </ul>
<b>Socio / Cultural</b>	<ul style="list-style-type: none"> <li>• Sustenance fisheries</li> <li>• Indigenous territories</li> <li>• Indigenous land claims</li> <li>• Public comments</li> <li>• Trespassing vessel</li> <li>• Media attention</li> </ul>

Table 1: Impact Factors

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### 3.3 Probability Factors

Probability factors are the likelihood that the hazard factors can materialize and can be expressed as the 'probability' axis in a risk matrix. Condition factors describe the probability that the condition of the vessel can degrade, and therefore increase the likelihood of a hazard materializing to one of the risk categories identified above, and the timeframe it would likely materialize within. The probability factors listed below in **Table 2** assessed through questions, depending upon the factor, in Phase 2 and Phase 3. Sections 4.2 and 4.3 detail these questions and potential responses.

#### Probability Factors

Categories	Factors
Environment	<ul style="list-style-type: none"> <li>• Shelter protection</li> <li>• How is the vessel secured?</li> <li>• Winter ice</li> <li>• Wash from passing vessel traffic</li> <li>• Accessibility by road</li> <li>• Accessibility by water</li> <li>• Nearby international border</li> <li>• Distance to deconstruction site</li> <li>• Vessel status (beached, grounded, sunk)</li> <li>• Water tight integrity</li> <li>• Mooring security</li> <li>• Anchor security</li> <li>• Seabed of anchorage area</li> <li>• Movement of vessel</li> <li>• Vessel list</li> <li>• Hull/deck deterioration</li> <li>• Water ingress</li> <li>• Oil sheen</li> </ul>
Physical State of the Vessel	<ul style="list-style-type: none"> <li>• Removal of pipework</li> <li>• Sewage leaking</li> <li>• Salvageable material</li> <li>• Lost net or lines</li> <li>• Size of the vessel</li> <li>• Depth of water</li> <li>• Number of VOCs in the immediate area</li> <li>• Vessel stability</li> <li>• Ground reaction</li> <li>• Structural integrity</li> <li>• Availability of general arrangements and capacity plans</li> </ul>
Pollutants Onboard the Vessel	<ul style="list-style-type: none"> <li>• Petroleum hydrocarbons on the vessel</li> <li>• Type of oil</li> </ul>

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Categories	Factors
	<ul style="list-style-type: none"><li>• Volume of oil</li><li>• Oil in machinery on the vessel</li><li>• Cargo onboard or lost</li><li>• Hazardous and noxious substances as cargo</li><li>• Hazardous materials on the vessel</li><li>• Refrigerants</li><li>• Unexploded ordinances or munitions</li><li>• Garbage on the vessel</li><li>• Response time with equipment</li><li>• Known owner</li><li>• Human activity on vessel</li><li>• Flag</li><li>• Vessel insurance</li><li>• History of past issues</li></ul>
Vessel Information	

Table 2: Probability Factors

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### 3.4 Probability and Impact Factors Considered

A number of probability and impact factor suggestions were received through engagement, however, not all were incorporated into the RAM. These are summarized below in **Table 3**.

#### Probability and Impact Factors Considered but Not Included

Factor	Rationale for Not Including
Upcoming commercial fisheries	Accessibility of data and assessing
Vessel from a Nation of importance to Government of Canada	This should not be a factor in assessing the risk the vessel poses
Sensitive ARGAs	Definition unclear – further clarity required
Decay Time	Difficult to obtain, maybe included in Phase 3
Flooding	Accessibility of data and assessing
Current/Wind Direction	Accessibility of data and assessing, and variables may change
Scheduled Public Events	Accessibility of data and assessing, and variables may change
Tax Payer Financial Burden	Very difficult to develop a scoring method to objectively assess this
Frequent TFC?	Definition unclear – further clarity required
Remedial Business Development	This should not be a factor in assessing the risk the vessel poses
Salt or Freshwater	Hard to justify a differing score for these two factors
Vessel Legal Conflicts	Need additional information on this factor prior to incorporating it
Violation of Local Bylaw	Legal consequences of including as a risk factor
Multiple Agency Stakeholders	Should not impact the risk score
Special Interest Groups	Had discussions during internal engagement session and for the time being, it was decided not to include
Archaeological Sites	This is very hard to evaluate as this is generally a provincial responsibility and each province has different levels of data availability and most of the data is protected. Known archaeological sites considered historic sites should be covered under historic sites factor.
Toxic Cloud Forming	Need highly specific details on the cargo, its properties and potential reactions. Also, would require a significant level of effort to determine with only minor impact on scoring. Would be captured already under presence of hazardous chemicals/materials aboard.
Severe Weather	Difficult to objectively answer, risk likely covered under sheltered environment factor
High Volume of Fast Water	Difficult to objectively answer, risk likely covered under sheltered environment factor

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Factor	Rationale for Not Including
Current Climate	Difficult to objectively answer, climate is for a large region and can sort Canada into different climate regions, but difficult to score
Fire Risk of Vessel	Is already addressed as a probability factor with flammables onboard and can the public easily access the vessel.

Table 3: Probability and Impact Factors Considered but Not Included

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# 4 Risk Assessment Methodology

## Conceptual Risk Assessment Model

The RAM is to be completed in five phases as follows:

- Phase 1 – Reporting Phase
- Phase 2 – Initial Risk Assessment
- Phase 3 – Technical Risk Assessment
- Phase 4 – Comprehensive Risk Assessment
- Phase 5 – Re-evaluation

The RAM methodology flow chart is presented in **Figure 1** shown below. The flow chart details the steps that would be followed to assess a VOC using the RAM and the necessary actions required to manage the risk posed by the VOC. It is not always required to conduct specific phases of the RAM and that their completion depends on the information required.

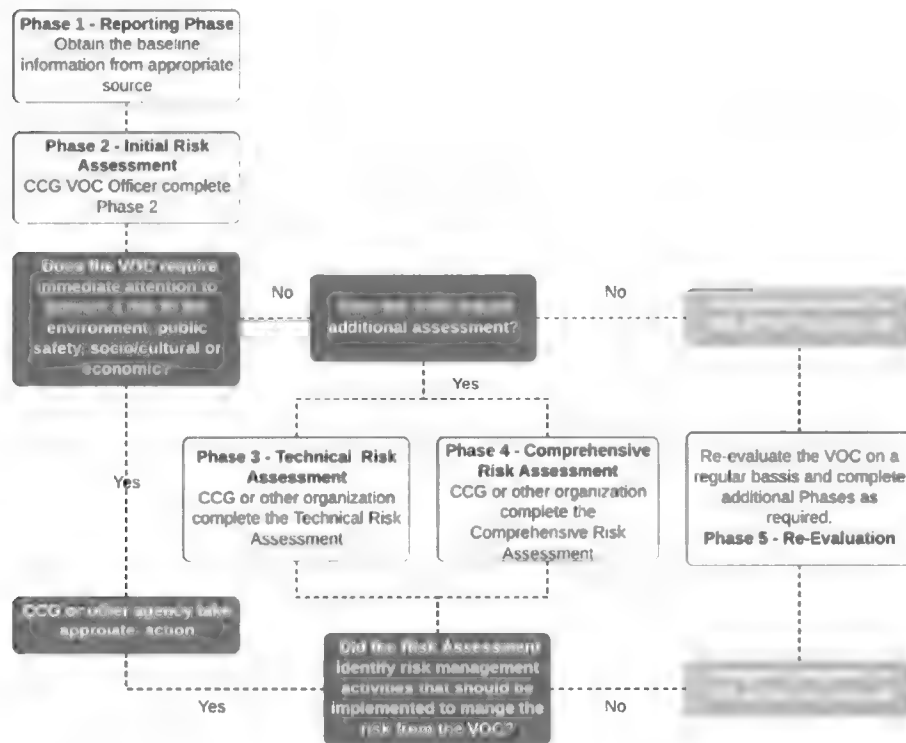


Figure 1: Conceptual Risk Assessment Methodology Flow Chart

## Risk Assessment Methodology

### 4.1 Phase 1 – Reporting Phase

This initial phase does not make a determination with respect to whether the vessel is a VOC or if it is to be dealt with by Coast Guard Environmental Response, it is expected that the decision to treat the identified vessel as a VOC has been made prior to initiating Phase 1. Phase 1 will commence when the details of the vessel are passed on to the VOC officer from the applicable Coast Guard Operational Centre. Upon receipt of the information the VOC officer will input the gathered information into the Risk Assessment Scoring Tool (RAST) and prepare for the Initial Risk Assessment (Phase 2).

The Phase 1 data gathering has been broken into four components to address both Coast Guard operational information needs as well as assessing the RAST. Those components are:

- VOC Intake
- VOC Description
- Pre-Assessment Screening
- Visit Records

Each of these components is discussed in the subsequent sections.

#### 4.1.1 VOC Intake

The VOC intake form (**Figure 2**) was developed from fields based on the National Inventory Template provided by Coast Guard. The intake form captures details related to the reporting of the VOC and does not contain information that will impact risk scoring.



## Risk Assessment Methodology

Survey123 for ArcGIS

**VOC Risk Assessment Scoring Tool**

**CCG Vessel of Concern Risk Assessment Tool**

Current Vessel Location:

51°3'N 114°3'W ± 141 m

**Vessel Initial Intake**

Info Entered By: \*

Name of the person that entered the VOC information into the Inventory

VOC File Number: \*

a number used to ID vessel in database

VOC Database ID:

VOC-20190826115927un37

Cross Reference File Number:

For an existing file number from another department

Reporting Party: \*

Initial Reporting Date: \*

Name of Person Reporting the Vessel: \*

Reporter Address: \*

Reporter Phone Number: \*

Reporter Email Address: \*

Reporter Organization: \*

Office of Primary Interest: \*

☐ CCG-ER ☐ CCG-VOC ☐ TC ☐ DFO SCH

☐ PC ☐ Other

Coast Guard Validated: \*

☐ Yes ☐ No ☐ Unknown

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Figure 2: Phase 1 VOC Intake Form

### 4.1.2 VOC Description

The VOC Description form (**Figure 3**) was developed from fields based on the National Inventory Template provided by Coast Guard as well as inventory details provided in Annex A/Annex 1 in the RFP. These details provide a general summary of mostly constant information related to the vessel and includes information that will not factor into the risk scoring. Data entered into this form, relevant to the risk scoring, will be automatically populated into the Phase 2 form.

## Risk Assessment Methodology

**VOC Risk Assessment Scoring Tool**  
CCG Vessel of Concern Risk Assessment Tool

Current Vessel Location:  
51°3'N 114°3'W ± 141 m

**Vessel Description**  
Vessel Summary

Vessel Name \*

Vessel Registration #  
only applicable to Canadian Vessels

Hull Identification #  
also known as "HIN" - the hull serial number, typically plated on the transom/stern of the vessel or SMO Number for international vessels

Commercial Fishing Vessel #:

Vessel Type \*

Vessel Category \*

Commercial: ☐ Pleasure Craft: ☐ Unknown: ☐

Vessel Length (meters):  
Enter exact length if known. Leave blank and select an appropriate category below if unknown.

Vessel Length Category \*

☐ <12 m ☐ >=12 and <20 m ☐ >=20 and <50 m ☐ >=50 and <100 m ☐ >100 m ☐ Unknown

Vessel Tonnage (gross tonnes):

Year Constructed \*

Vessel Flag \*

☐ Canadian ☐ Other ☐ Unknown

Vessel Hull Material \*

Vessel Status \*

Beached/Ashore ☐ Grounded/Partly Grounded ☐ Floating/Assumed floating Anchored ☐ Floating/Assumed floating Moored ☐ Overturned/Capsized ☐ Sunk/Partially Sunk ☐ Unknown

Vessel Description \*

Provide a detailed description of the vessel including the construction, colour and any other observable details of the vessel.

Vessel Owner or Authorized Rep (Name) \*

Vessel Owner/Rep Address \*

Vessel Owner/Rep Phone # \*

Vessel Owner/Rep Email \*

Does Vessel Have Insurance? \*

Yes ☐ No ☐ Unknown ☐

Location of Vessel

Vessel Description Photos

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**VOC Risk Assessment Scoring Tool**

**Location of Vessel**

General Location: \*

Coast Guard Region: \*

☐ Arctic ☐ Atlantic ☐ Central ☐ Western

Province: \*

Waterbody: \*

Vessel located in SCH? \*

☐ Yes ☐ No ☐ Unknown

Indigenous Considerations / Land Claim? \*

☐ Yes ☐ No ☐ Unknown

Is the vessel itself a tourist site? \*

Some VOCs are managed locally for tourists. If this is the case then answer yes. If the vessel is at a tourist site but is not the main draw, respond no.

☐ Yes ☐ No ☐ Unknown

Tourist Site Comment:

Overall Status Notes:

Remediated? \*

☐ Yes ☐ No ☐ Unknown

Current Risk Assessment Phase?

☒ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Vessel Description Photos

Vessel Overview Photo

Take or upload representative overview photo of vessel.

Vessel Description Photo 1 (out of maximum 5):

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Figure 3: Phase 1 VOC Description Form VOC Pre-Assessment Screening

Prior to conducting Phase 2 through Phase 5, or if conducting a site visit, a series of questions will be posed that would immediately rank the vessel as high risk and require action, negating the requirement for completing the subsequent phases. The questions for the Pre-Assessment Screening are shown in Figure 4.

## Risk Assessment Methodology

Survey123 for ArcGIS

**VOC Risk Assessment Screening Tool**

**CCG Vessel of Concern Risk Assessment Tool**

Current Vessel Location:  
☐ 51°3'N 114°3'W ± 141 m

**Pre-Assessment Screening**

Is there evidence of the vessel leaking oil into the water? \*

☐ Yes ☐ No

Is the vessel taking on water or in danger of sinking? \*

☐ Yes ☐ No

Is there current criminal activity or evidence of recent criminal activity on the vessel? \*

☐ Yes ☐ No

Does that vessel have the potential to impend navigation? \*

☐ Yes ☐ No

Is the vessel in danger of breaking loose from its moorings (whether tied up alongside, at anchor or aground)? \*

☐ Yes ☐ No

Are there concerns that the vessel is not safe to enter for the purposes of completing this assessment (i.e.: is gas testing required, are there confined spaces, is the mold an issue, is the vessel safe to walk on, is the vessel stable). \*

☐ Yes ☐ No

Is there a live aboard owner on the vessel? \*

☐ Yes ☐ No

4 of 9

Figure 4: Phase 1 VOC Pre-Assessment Screening VOC Visit Records

It is recognized that some attributes of the vessel and surrounding area will be subject to change over time, and those changes could impact the risk scoring. The VOC Records form is meant to capture details about the vessel at the initial site visit and all subsequent visits. Changes in these attributes will serve as indicators that the vessel status may be changing or has the potential to change. Information captured on the form relevant to risk scoring will be auto-populated into the Phase 2 form. The information captured in the form includes:

1. Date of visit
2. Position of the Vessel (determined by the tool)
3. Date of the Survey
4. Name of the Surveyor
5. Visibility of an oil sheen
6. Vessel draft details
7. Vessel photos
8. Vessel list
9. Moorings
10. Evidence of chafing
11. Evidence of sun damage

## Risk Assessment Methodology

12. Water ingress information
13. General vessel condition
14. Signs of human activity
15. Mooring infrastructure deterioration
16. Number of VOCs in area
17. General comments

A figure showing the general layout of the form used to collect the site visit records is presented in Figure 5.

The screenshot displays the 'VOC Risk Assessment Scoring Tool' interface. The top section includes a title bar and a menu icon. Below this, the 'CCG Vessel of Concern Risk Assessment Tool' is identified. The 'Current Vessel Location' section shows coordinates (51°3'N 114°3'W ± 100 m) and a satellite map. The 'VOC Visit Records' section contains fields for Latitude, Longitude, and Latitude/Longitude DMS (51°02'31.2"N 114°03'27.1"W), along with Survey Date and Surveyor. The 'Oil Sheen?' section has a Yes/No radio button. The 'Vessel Draft' section includes Units (Metres/Feet), Forward (m), Aft (m), and Trim (m) fields. The 'Water Ingress' section has a Water Ingress Location field, Units (Centimetres/Inches), Depth of water (cm), and a Location of measurement field. The 'Moorings' section includes Total Number of Lines, Number of Broken Lines, Evidence of Chafing, Evidence of Sun Damage, and a Photo 1 of Moorings (max 5) field. The 'Vessel General Condition' section includes Vessel Status (Beached/Ashore, Grounded/Partly Grounded, Floating/Assumed Floating Anchored, Floating/Assumed Floating Moored, Overturned/Capsized, Sunken/Partially Sunk, Unknown) and Vessel Condition Comments. The 'Human Activity' section includes Alcohol?, Drug Use?, Trespassing?, and Other Criminal Activity? fields. The 'Mooring Infrastructure Deteriorating?' section includes a field for Is there evidence of any deterioration in the jetty/wharf, mooring connections etc. and a Mooring Infrastructure Deterioration Photo 1 (of max 2) field. The 'Number of VOCs in area' section includes a field for What is the total of VOCs in the same area? Add notes to general comments. The 'General Comments' section includes a field for Any other details (eg signs of any maintenance, met with owner, VOCs in area etc.). The 'Vessel Photo 1 (out of maximum 10)' section includes a photo upload field. The bottom of the interface shows a page number '1 of 1' and a total of '5 of 9' pages.

Figure 5: VOC Vessel Records

## Risk Assessment Methodology

### 4.2 Phase 2 – Initial Risk Assessment

The Initial Risk Assessment Phase will be a series of questions that the regional Coast Guard VOC officer will answer. Some or all the information may already be available and have been inputted in Phase 1 as a result of prior interaction with the vessel; or a visit to the VOC may be required. These questions focus on identifying potential probability and impact factors in relation to the VOC. To make the methodology intuitive and to allow a variety of persons to complete the Initial Risk Assessment, it is anticipated that the responses to the probability and impact questions, used to complete the Initial Risk Assessment, will be either “yes”, “no” or “unknown”. A different score will be given for each answer. An example of a potential impact factor and a probability impact question are as follows:

- Impact Factor – Is the vessel located in Indigenous territory? (yes = a score of 10, no = a score of 0 and unknown = a score of 5).
- Probability Factor – Does the vessel contain petroleum hydrocarbons (yes = a score of 10, no = a score of 0 and unknown = a score of 5).

The impact factor questions for Phase 2 are grouped into the four risk categories. At this phase, the questions focus on information that is ideally accessible at a desktop level. Questions and responses from Phase 1 relevant for Phase 2 are auto-populated in Phase 2, as applicable, without the need for re-entry.

The probability factors for Phase 2 are grouped into four general categories. Questions and responses from Phase 1 relevant for Phase 2 are auto-populated in Phase 2, as applicable, without the need for re-entry.

The score assigned to each of the questions will be combined to yield an Initial Risk Assessment Score (IRAS) that will enable the vessel to be ranked and compared to other vessels in the VOC inventory to allow for prioritization and decision-making. The IRAS calculated will be plotted in a 5x5 risk matrix with the impact factors on one axis and the probability factor on the other as illustrated in **Figure 6**.

## Risk Assessment Methodology

Probability Factors	III	IV	IV	V	V
	III	III	IV	IV	IV
	II	III	III	IV	IV
	II	II	III	III	IV
	I	II	II	III	III
Impact Factors					

Figure 6: Example of the 5x5 risk matrix that would be used to illustrate the resulting Initial Risk Assessment Score

At the completion of Phase 2, the tool will generate the initial risk score of the vessel as well as possible maximum and minimum scores based on worst-case and best-case scoring for all questions for which “unknown” was selected. The outputs will also inform the Coast Guard if they must continue on with the risk assessment process or if the Initial Risk Assessment Phase provides sufficient information to inform decision making. It is anticipated that the Initial Risk Assessment will be robust enough to allow for the vast majority of the risk assessments for VOCs to end at this point. However, for the vessels that require additional assessment, the Coast Guard will carry on with the Technical Risk Assessment (Phase 3).

## Risk Assessment Methodology

### 4.3 Phase 3 – Technical Risk Assessment

If deemed necessary, a Technical Risk Assessment will be completed. The objective of the Technical Risk Assessment is to complete a detailed examination of the vessel to determine and quantify the level of risk it poses. In many cases the Technical Risk Assessment will be required to provide definitive responses to questions posed in Phase 2 - Probability Factors that returned "Unknown". It is envisioned that this phase will be undertaken by a qualified Naval Architect / Marine Engineer with experience in assessing VOCs. It is expected that the assessment will produce a descriptive report which will then allow the VOC team to complete the Phase 3 questionnaire. In addition to providing the responses to the Phase 2 "Unknowns" the report will include as a minimum the following:

- Assessing the structural integrity of the vessel including, where necessary, calculations to support conclusions
- Stability of the vessel in its current state. If the vessel is floating, comment should be made on the ballast condition and whether it is adequate
- The risk of the vessel to pollute the surrounding environment including volume and types of pollutants aboard
- The ability of the vessel to float and/or remain floating
- The likelihood of the vessel remaining in its current location (safely moored, anchored, aground, sunk, etc.)
- An assessment of the hazardous material onboard
- Any risk to public safety if not already assessed in Phase 2
- Review of available documentation and comment on whether the necessary information is available should further assessment or remedial action be required
- In the case of sunken vessels where the quantity of pollutants onboard is unknown the report should contain guidance to allow the VOC team to adequately consider options for further work

Where appropriate the assessment will also include a range of options with cost estimates, timelines and level of effort to address the risk posed by the vessel and may include options for disposal. To ensure that the assessment report contains the necessary information to complete the Technical Risk Assessment questionnaire, a detailed examination report template will be developed that the VOC team can issue to specialized contractors who will complete the detailed examination. Having the contractors each use the template will help ensure that the necessary information is available in the report and it is always located in the same section of the report.



## Risk Assessment Methodology

The information contained in the detailed examination report will be incorporated in the Technical Risk Assessment module of the overall Risk Assessment. The Phase 3 worksheet will autopopulate the questions from Phase 2 probability factors for the four categories: Environment, Physical State of the Vessel, Pollutants onboard, and Vessel Information. In addition to providing definitive responses to the "unknowns" from Phase 2, additional questions will be posed. This will allow the risk score obtained following Phase 2 to be refined and increase the confidence factor.

This is best demonstrated through an example that builds on the Probability Factor example presented in Phase 2: Probability Impact – Does the vessel contain petroleum hydrocarbons (yes = a score of 10, no = a score of 0 and unknown = a score of 5). This will be modified during the Technical Risk Assessment to yield a revised score based on the volume of petroleum hydrocarbons onboard as presented in **Table 4**.

Volume of Oil Onboard	Score
Negligible (<1m3)	1
Minor (>1m3 -<5m3)	2.5
Moderate (>5m3 - <50m3)	5
Severe (>50m3 - <100m3)	7.5
Catastrophic (>100m3)	10
Unknown	5

Table 4: Scoring Scheme in Ram for Volume of Oil Onboard the VOC

The Technical Risk Assessment Score (TRAS) will modify and expand on the scoring calculated during the Initial Risk Assessment. The methodology determines the TRAS will be coded to allow for the modification of each of the factors when more information is available. This provides the VOC team with a flexible tool that can generate risk scores for each Phase completed while still being easy to use.

At the completion of Phase 3, the VOC team will have a revised risk score plotted on a risk matrix (**Figure 5**) to account for the new information provided by the detailed evaluation. The Percent Response will be calculated and reported with the TRAS.

It is anticipated that if a Technical Risk Assessment is completed, a Comprehensive Risk Assessment will also be completed (Phase 4). However, Phase 3 and Phase 4 are independent, Phase 4 does not require the completion of Phase 3 and vice versa.

## Risk Assessment Methodology

### 4.4 Phase 4 - Comprehensive Risk Assessment

While Phase 3 examined the structural integrity and pollution potential of the VOC, the Comprehensive Risk Assessment (Phase 4) assesses the potential impact the VOC could have on the environment, local economy, public safety and socio-cultural receptors. This phase is designed to build and expand upon the information collected in Phase 2. This phase is designed to be completed by a Coast Guard VOC Officer or could be done by a contractor. It is expected that the person completing the Comprehensive Risk Assessment will not require any special training, education or skill set and that it can be done using readily available and open sources of data. The Comprehensive Risk Assessment will not be a Human Health or Ecological Risk Assessment (HHERA) but will be a qualitative assessment of what environmental, local economic, public safety and socio-cultural receptors could be impacted by the VOC.

To properly complete the Comprehensive Risk Assessment, it is expected that the information necessary to evaluate the risk will be collected from desktop studies as well as a site visit (if required). The desktop studies will provide the necessary background/baseline information to adequately assess the risk to the environment, economy, public safety and socio-cultural receptors. Background/baseline information that could be reviewed include websites, published reports and previous risk assessments completed.

Upon completion of the background/baseline desktop study a contractor or VOC officer will conduct a site visit, if required, to obtain any missing information not obtained during the baseline/background desktop review. However, there are certain components of the Comprehensive Risk Assessment that may require specific technical input either from other government departments (OGD) or contractor to allow for a complete assessment. The use of OGD is the exception and will only be used in select circumstances to further refine the score. For example, if the vessel has oil onboard and is located in a marine protected area, oil spill fate and trajectory modelling may be completed to determine the impact an oil spill could have on the marine protected area.

Similar to Phase 3, the Comprehensive Risk Assessment will build and expand upon the information collected and scored during previous phases. New questions will be posed for the four risk categories, as well as more detailed questions based on the responses to questions from Phase 2. The more detailed responses will be used as modifiers for the risk score calculated for that factor in Phase 2. Examples of risk modifier questions in Phase 4 are shown in **Table 5** below.

## Risk Assessment Methodology

Factor	Phase 2 Question	Phase 2 Response	Phase 2 Score	Phase 4 Modifier Question	Phase 4 Responses/Modifiers	Revised Score
<b>Environment</b>	Are there any Marine Protected Areas within 5 km?	Yes	10	If yes, what is the distance from the VOC?	Within 5km (5)	10
		No	0		More than 1 within 5 m (10)	
		Unknown	5		Within 500 m (10)	
<b>Economic</b>	Are there any known commercial fisheries within 5 km?	Yes	10	Is it likely to impact?	Yes(1)	7.5
		No	0		No(0)	
		Unknown	5		Unknown (1)	
<b>Public Safety</b>	Does the vessel have the potential to become a navigational hazard?	Yes	10	Is it impacting commercial or recreational activities?	Yes (1)	10
		No	0		No(0.25)	
		Unknown	5		Unknown (1)	
		No	0			
		Unknown	5			

Table 5: Example questions, responses and revised scores that will be used during the Comprehensive Risk Assessment

Upon completion of Phase 4 the Coast Guard will have a revised risk score for the VOC. The new risk score will be plotted on a risk matrix (**Figure 5**) which will help illustrate what is driving the risk score and what additional activities (e.g. removal of vessel or draining of fuel tanks) is required to risk manage the VOC.

### 4.5 Phase 5 – Re-Evaluation

Phase 5 re-evaluates the VOC as action is taken to mitigate/reduce the potential risk from the VOC or if changes occur to the VOC and/or surrounding environment. The purpose of this phase is to determine if the actions completed effectively mitigate the risk that the VOC poses or if changes to the vessel or environment further increase the risk of the VOC. The exact data to be re-evaluated will be based on a case-by-case basis and will not necessarily require the Coast Guard to repeat Phase 2 to 4 in their entirety.

The RAM is flexible so that only the factors that have changed can be modified and a new risk score can be generated. The revised risk score that is generated as part of Phase 5 will once again be plotted on a risk matrix and a revised Percent Response will be generated.

It is anticipated that a re-evaluation will be completed when one or more of the following has been carried out:

## Risk Assessment Methodology

- Remedial activities are completed on the vessel (oil/hazardous material removed)
- Vessel is shored up (tied up more securely)
- Vessel security is increase to further restrict public access.
- Vessel is relocated
- Vessel sinks

### 4.6 Confidence Level Determination

As a part of the RAM, a Confidence Level will be generated. The Confidence Level will be calculated for the individual elements of the impact and probability factors at each Phase. This confidence interval will be determined from unknowns and the potential minimum and maximum scores that could be generated by answering all unknowns at that phase. This will enable the assessor to understand how the risk score could change with responding to all unknowns and if it would result in a change in the risk definition of the vessel and subsequent required action.

## Risk Assessment Methodology

### 5 Calculation and Interpretation of Risk Score

A risk score will be generated for each phase of the RAM, excluding Phase 1, by using the calculation procedure described herein. The impact and the probability factors are modified by an Importance factor. The importance factor enables the assignment of differential weighting to each of the impact and probability factors based on its perceived importance.

#### 5.1 Impact Factor weighting

It is recognized that the environmental impact factors need to have a greater influence on the overall risk based on feedback obtained during engagement and therefore the impact importance factors have been set as follows:

Environmental	40%
Economic	20%
Public Safety	20%
Socio-Cultural	20%

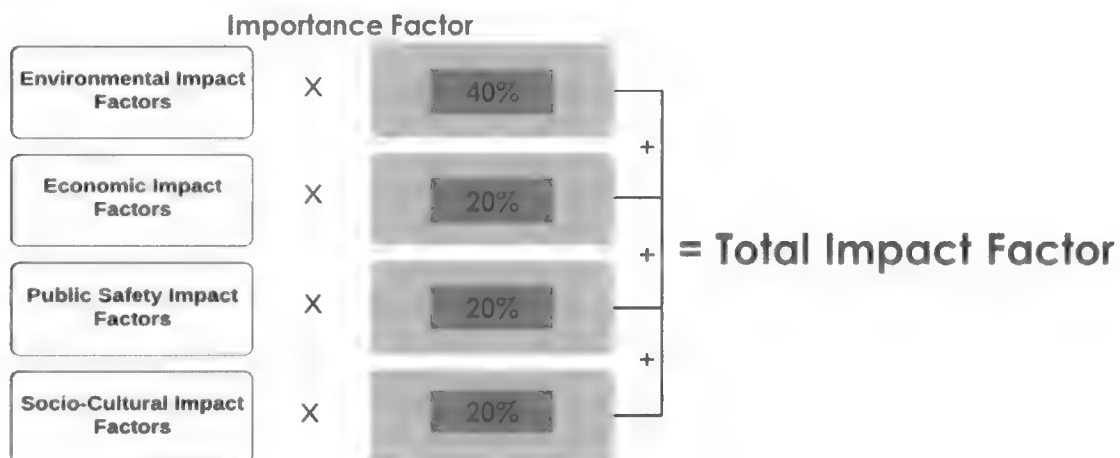


Figure 7: Impact Weighting Factors

## Risk Assessment Methodology

### 5.2 Probability Factor Weighting

After consideration, it was established that the Physical State of the Vessel and the Pollutants onboard have a significantly higher influence on the risk profile than the surrounding environment or information available on the vessel. Therefore, the importance factors have been updated as detailed below:

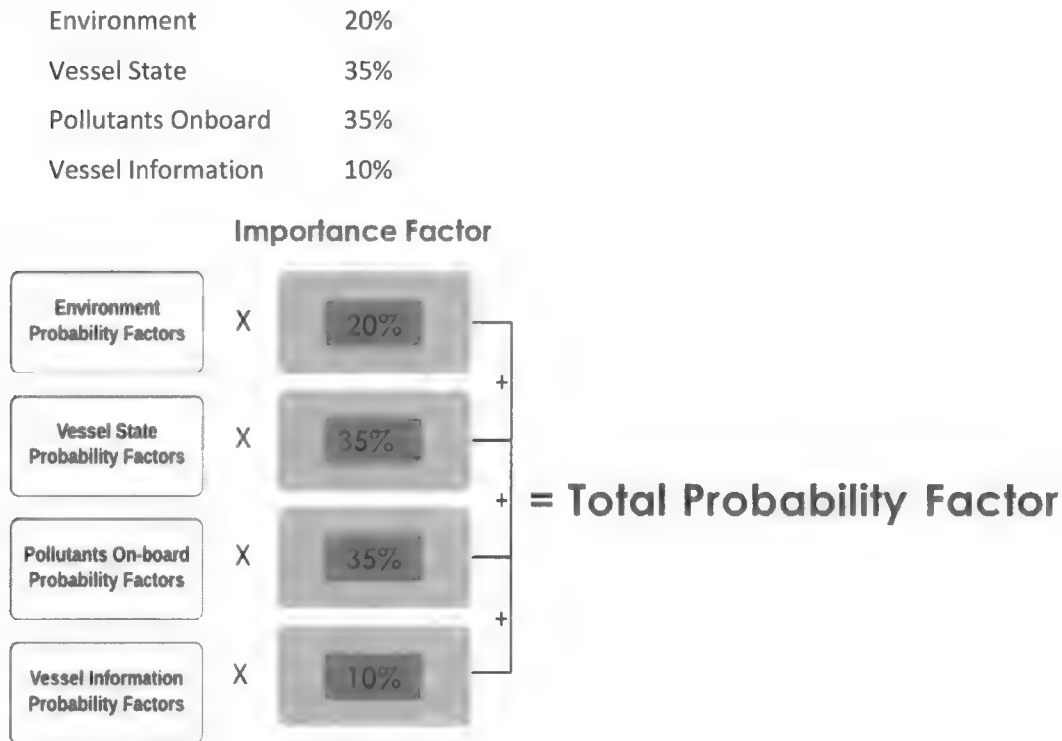


Figure 8: Probability Weighting Factors

## Risk Assessment Methodology

### 5.3 Vessel Length Weighting Factors

In order to differentiate between vessels of different sizes a further weighting factor is applied to the Total Probability Factor to give an Overall Probability Factor. **Table 6** below details weighting factor applied for various length intervals.

A weighting based on the vessel's length is used to modify the overall probability score to get the total probability score					
Vessel Length	<12m	12 – 20m	20 – 50m	50 – 100m	>100m
Weighting factor	1	1.05	1.1	1.25	1.35
<b>Total Probability Score X Length Weighting Factor = Overall Probability Score</b>					

Table 6: Vessel Length Weighting Factors

### 5.4 Total Risk Score

The Total Risk Score for each vessel is calculated as follows:

$$\text{Total Impact Score} \times \text{Overall Probability Score} = \text{Total Risk Score}$$



## Risk Assessment Methodology

### 5.5 Risk Matrix

After completing each phase of the RAM, excluding Phase 1, the Coast Guard will have a risk score that can be plotted on the VOC RAM Risk Matrix.

Where the risk score falls within this risk matrix will dictate what actions and next steps will be required. The risk matrix illustrating the five areas on the risk matrix is presented in **Figure 9**. Depending on where in the risk matrix the risk score falls and what Phase has been completed will dictate what next steps have to be completed. **Table 7** presents the preliminary risk management categories outlined in the Risk Matrix and what actions should be undertaken, if required, to effectively risk manage the VOC. However, the risk management categories and required actions will need to be confirmed based on the risk tolerance of Coast Guard during program development.

The RAM will generate a score for each of the impact and probability factors and how they are influencing the overall score. This will enable the Coast Guard to evaluate the effectiveness of various risk management techniques to see which one is the most cost effective and provides the greatest reduction in the risk score.

Probability Factors	III	IV	IV	V	V
	III	III	IV	IV	IV
	II	III	III	IV	IV
	II	II	III	III	IV
	I	II	II	III	III
Impact Factors					

Figure 9: VOC Risk Matrix illustrating the five areas where a risk score could be

## Risk Assessment Methodology

Risk Area	Definition	Action per each Phase		
		Phase 2	Phase 3	Phase 4
I	<b>Very Low Risk</b>	No further action required at this time	No further action required at this time.	No further action required at this time
II	<b>Low Risk</b>	No further action required at this time	No further action required at this time.	No further action required at this time
III	<b>Medium Risk</b>	Complete Phase 3	Complete Phase 4	Undertake risk management actions
IV	<b>High Risk</b>	Immediately complete Phase 4	Undertake risk management activities and complete Phase 4	Undertake risk management activities
V	<b>Very High Risk</b>	Consider undertaking risk mitigation measures immediately, including moving/remediating vessel.	Consider undertaking risk mitigation measures immediately, including moving/remediating vessel.	Consider undertaking risk mitigation measures immediately, including moving/remediating vessel

Table 7: Risk area definitions and actions recommended for each phase

## Risk Assessment Methodology

### 6 Risk Assessment Tool

The Risk Assessment Tool has two main components, with each component developed to provide the necessary information to the Coast Guard for managing the VOC program.

The two components are as follows:

1. A method to assess the potential risk associated with each VOC – the Risk Assessment Scoring Tool (RAST)
2. A method to understand and evaluate potential risk mitigation options – the Risk Mitigation Tool (RMT)

The RAST and RMT are separate components of the Risk Assessment Tool and rely upon the same underlying technology allowing for a seamless transition of information through the assessment, analysis, and mitigation stages of VOC management.

The software and technological tools use for each of the components are explained in detail in the subsections below and are summarized in **Figure 10** below. Details on how to use the tools are provided in the User's Guide under separate cover.

## Risk Assessment Methodology

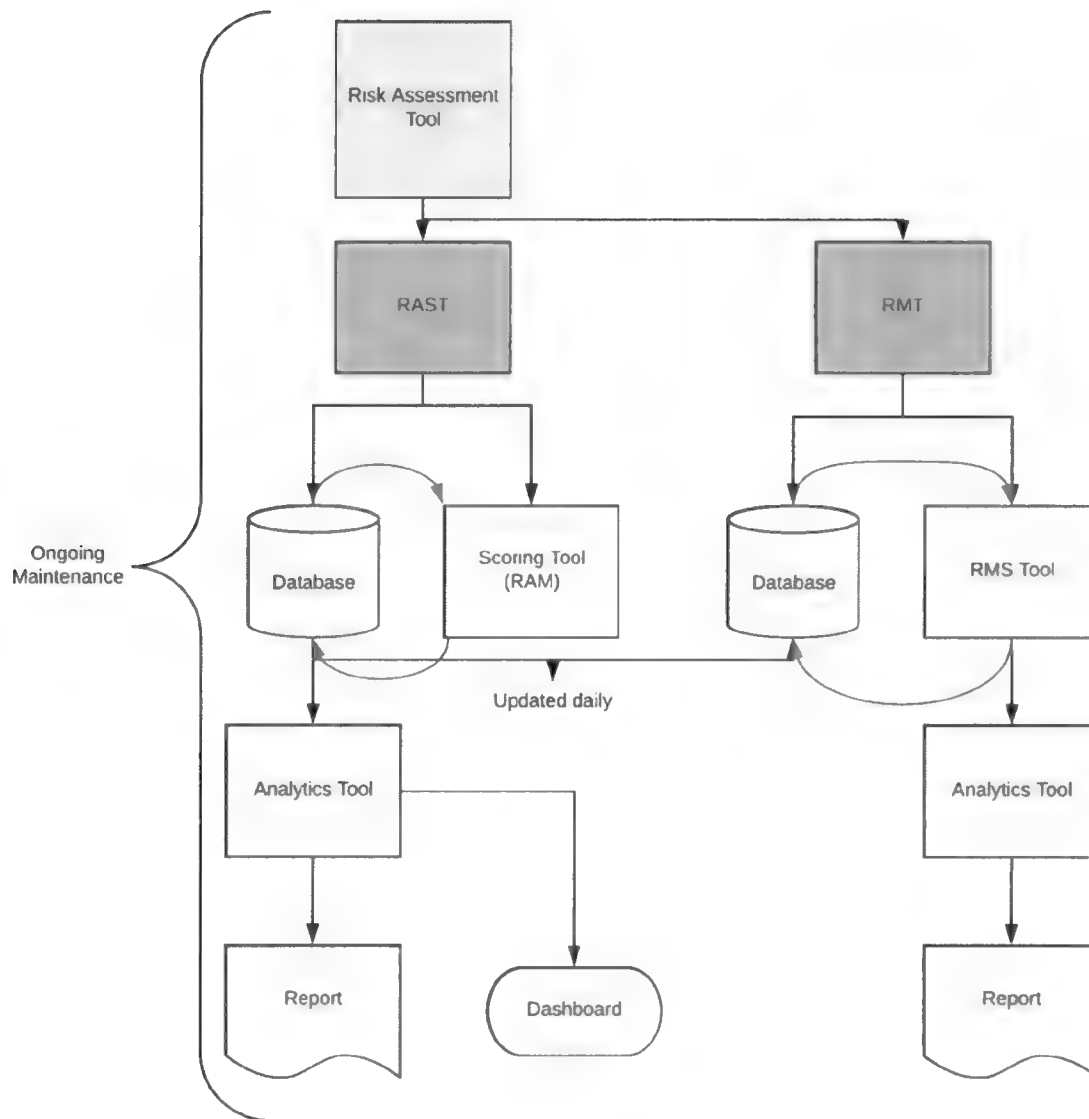


Figure 10: Conceptual model for the Risk Assessment Tool

## Risk Assessment Methodology

### 6.1 RISK ASSESSMENT SCORING TOOL (RAST)

The Risk Assessment Scoring Tool (RAST) provides a data management framework for making the most effective use of the developed RAM. The three components of the RAST are as follows:

- A method to assess multiple VOCs in the field and then report the results back
- A georeferenced VOC database that contains the records of the assessed VOCs using the RAM as well as the VOCs that have yet to be assessed
- A method to display information contained in the georeferenced VOC database including the outputs of the RAM, and a method to graphically display the contents for the database to allow for Coast Guard VOC program officers to easily obtain decisions on VOCs, and to enable decision making on a national, regional and local scale about VOCs

#### 6.1.1 Data Acquisition

Existing Coast Guard VOC data has been incorporated into the RAST database. In consultation with Coast Guard the data fields have been reviewed for potential optimization in design to limit future transcription ambiguity and to optimize field data collection and future analyses.

A thematic data gathering exercise has been completed to support the RAST. These are publicly-available datasets that will expedite responses to questions associated with environmental and socio-economic features in the vicinity of current and potential future VOCs. Other data sets that are not publicly-available can be included as required. This list includes data such as:

1. Ecologically Sensitive Areas (Marine Protected Areas, National Wildlife Areas, Important Bird Area, etc.)
2. Recreational Land Use and High-Density Population Areas
3. Indigenous Communities
4. Commercial Fisheries
5. Shoreline Classification

These datasets are used in spatial analysis scripts to auto-populate attributes (e.g. distance from nearest Marine Protected Area) that would be required for the RAM. These scripts are automated to be run at defined times to keep these attributes up to date for the entire VOC database. This is anticipated to reduce significantly on manual input of data into the RAM for VOC officers.

Ongoing maintenance of these datasets is anticipated to be a requirement of the Risk Assessment Tool as relevant external datasets are updated (e.g. addition of a new Marine Protected Area).

## Risk Assessment Methodology

### 6.1.2 Database Design

The RAST VOC database has been designed and developed within the *ESRI ArcGIS* environment. The database has been developed concurrently with probability and impact factors and risk scoring methodology. The design focuses on necessary data collection fields while minimizing the likelihood of transcription errors and ambiguity in data entry. Where reasonable, fields are drop down menu choices to enable consistent and standardized data entry protocols.

Once hosting has been finalized the database will be moved to *ArcGIS Online* to take advantage of the flexible and customizable data editing and viewing applications available within the environment. A web application has been developed to support both data editing and viewing based on the RAST VOC database. Through coding *ArcGIS Online* allows for the creation of dynamic attributes on a database during data collection. The RAM probability and impact factors and risk scores have been coded in this fashion based on the existing and future data entered into the RAST VOC database. As field surveys for each phase are completed the factors and scores will update automatically to reflect current data. Datasets collected in the acquisition phase will be available in desktop and field editing and viewer applications as appropriate. This will enable quick access to relevant data for answering RAST questions, as well as supporting decision making. Web maps allow for all users to have access to the same dataset simultaneously while allowing for dynamic views at any desired scale, and a variety of choices in base maps.

### 6.1.3 Data Collection

*Survey123* is the field data collection applications of choice, in addition to a desktop editing application. The application connects directly to *ArcGIS Online* and allows for direct syncing to the RAST VOC database if an internet connection is available or in an offline mode until one becomes available. *Survey123* is a form-centric data collection application allowing for more options in terms of base data and spatial data editing. The application works on a variety of tablets and smartphones (iOS, Android, and Windows) as well as web browsers. The application has the ability to support the uploading of photos and videos as attachments to collected data in the field.

Phase 1 commences when the details of the vessel are passed on to the VOC officer from the applicable Coast Guard Operational Centre. Phase 1 data is anticipated to be static data about the vessel such as Vessel Name, Vessel Type, Vessel Registry Number, etc. This data is anticipated to be relevant to the operational management of VOCs but may not be directly relevant to risk scoring. A web map version n will be available to support desktop data entry as well. Identified critical thematic datasets will be available as base layers in the field and desktop applications.

## Risk Assessment Methodology

*Survey 123* is the primary data collection application for VOCs when completing risk assessment surveys (Phase 2 – Initial Risk Assessment, Phase 3 – Technical Risk Assessment and Phase 4 – Comprehensive Risk Assessment), given the dynamic nature of these assessments depending upon the vessel. The application allows for smart form development, where subsequent questions are driven by earlier responses, creating a streamlined and intuitive data collection process. It also allows for risk scores to be calculated dynamically as questions related to each impact and probability factor are answered through each risk assessment phase. This will allow for a risk assessment score to be automatically calculated at the completion of each assessment phase.

It is understood that, through mitigation activities, risk assessment surveys may need to be repeated as changes to the VOC or surrounding environment occur. The RAST VOC database and risk assessment surveys are designed to retain previously collected data to capture the life cycle of a VOC's management.

Included in the web application are a number of pre-defined report formats as well as “dashboards”. These have been developed after consultation with Coast Guard.

Detailed instructions on how to use *Survey 123* and the web-based database are included in the **User Manual**.

### 6.1.4 Notepad

Separate to the data collection there is a “Notepad” function attached to each VOC. It is envisaged that this will be used to maintain a chronological log of actions taken such as communications with vessel owners, lawyers etc.

## 6.2 Risk Mitigation Tool

The Risk Mitigation Tool (RMT) is a separate component of the Risk Assessment Tool from the RAST but relies upon the database structure and data collection to inform potential future actions. The RMT will access a version of the Risk Assessment Tool database that allows for manipulations, separate from the Risk Assessment Tool database. This is an interactive planning tool, allowing for operational staff to see the potential impacts on future mitigation activities on the overall risk score for the VOC and undertake risk management actions accordingly. The RMT has two main components:

1. A version of the RAST database – the RMT database.
2. A Risk Mitigation Scoring (RMS) Tool.

The RMT database will be updated on a regular basis as required in order to reflect as current a version of the RAST database as possible. Data manipulation of this database will be separate from the RAST as this is for future planning scenarios and the RAST should reflect the actual current state of each VOC.

## Risk Assessment Methodology

The RMT tool has similar functionality as the RAST data analysis and reporting tools, but with added functionality to analyze potential future mitigation activities and their impacts.

Operational staff have the ability to:

1. Select from a list of possible mitigation actions that will automatically re-calculate the overall risk score for the vessel based on the options selected
2. Modify individual attributes and dynamically see the changes to probability and impact factors, and the overall risk score for the VOC

### 6.2.1 Remediation Record

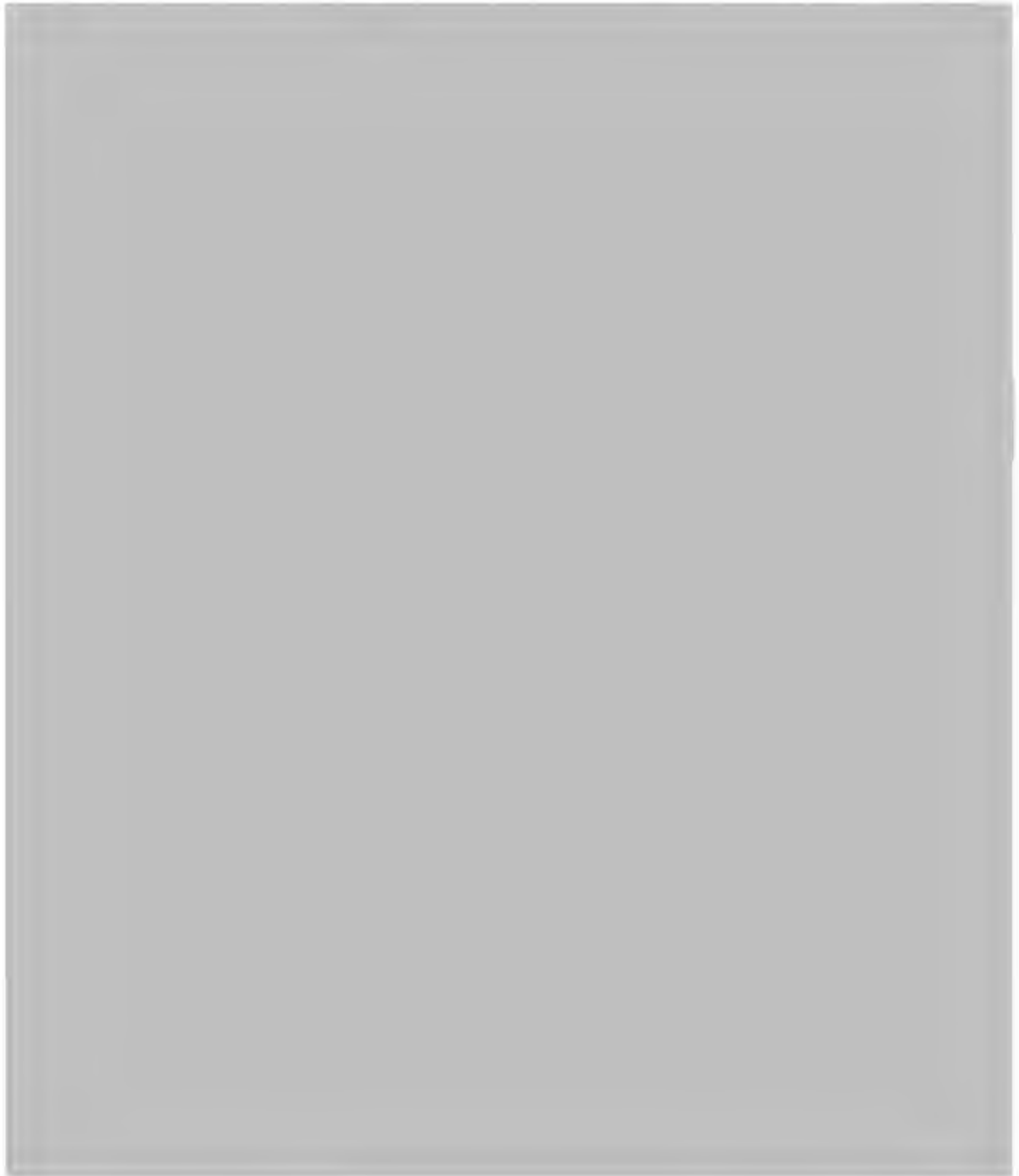
*Survey 123* is also used to record details of remediation actions and contains the following fields:

- Date
- Remediation Action Type
- Brief Description of Operation
- PSPC Contract No.
- Contractor(s)
- Contract Award Value
- Final Contract Cost
- Duration of Remediation Works (No. of Days)
- Comment

Initially this will just provide a record of remediation for a particular VOC. However, as the information will be stored in a database format, in time this will provide a useful resource for planning purposes.



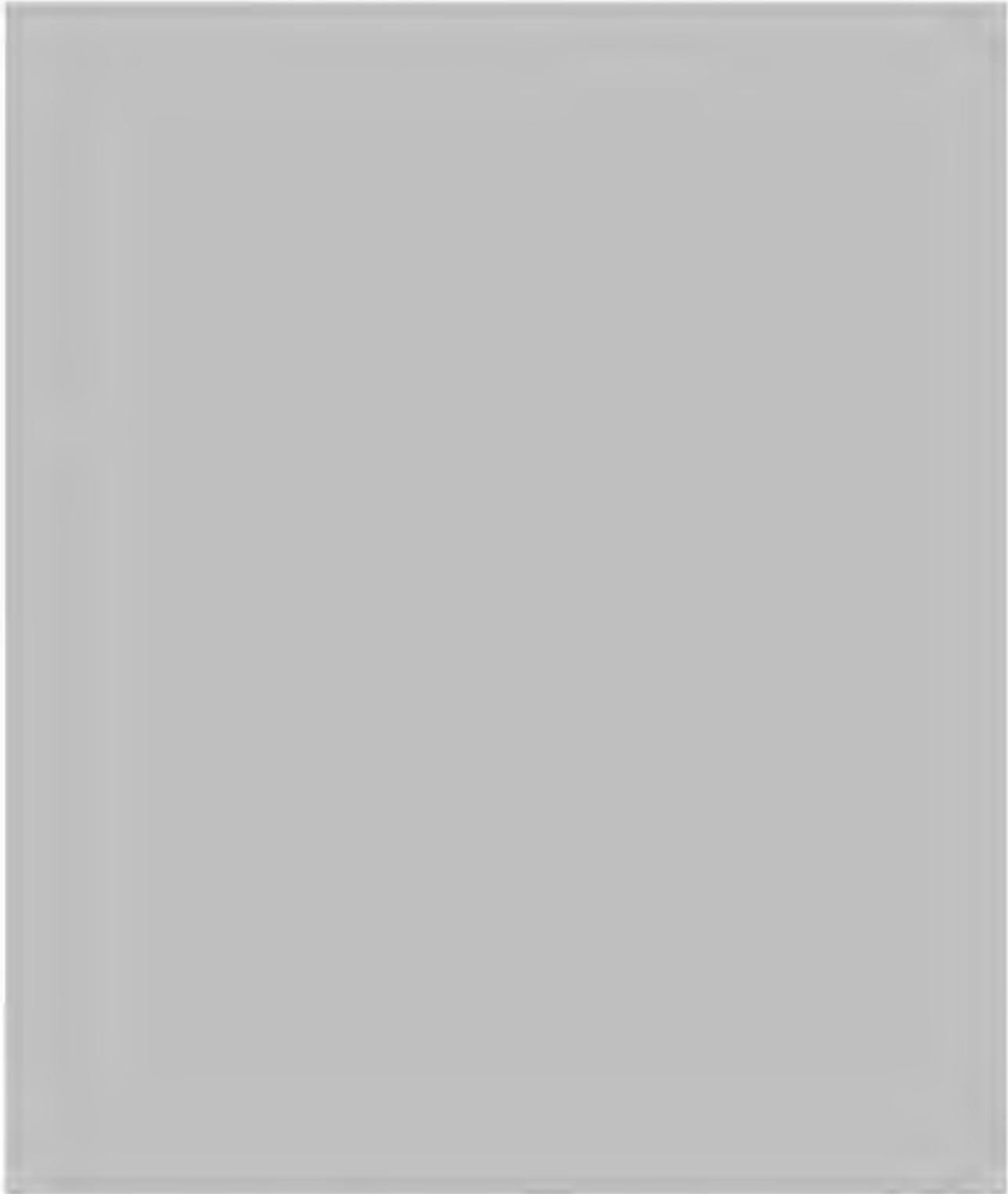
## Risk Assessment Methodology



## Risk Assessment Methodology



## Risk Assessment Methodology



## ***Appendix A - Glossary of Terms***

**Risk**, for the purpose of the VOC RAM, is defined as the combination of impact factors with probability factors.

**Hazard** means any condition or threat that:

- (a) poses a danger or impediment to navigation; or
- (b) may reasonably be expected to result in major harmful consequences to the marine environment, or damage to the coastline or related interests of one or more States.

6. "Related interests" means the interests of a coastal State directly affected or threatened by a wreck, such as:

- (a) maritime coastal, port and estuarine activities, including fisheries activities, constituting an essential means of livelihood of the persons concerned;
- (b) tourist attractions and other economic interests of the area concerned;
- (c) the health of the coastal population and the wellbeing of the area concerned, including conservation of marine living resources and of wildlife; and
- (d) offshore and underwater infrastructure.

It does not include harmful consequences that are excluded by the regulations.

**Risk factors** are the types of factors that must be assessed to determine the level of risk presented by a vessel. These are Impact Factors and Probability Factors. Combined, the Impact and Probability Factors are entered into the RAM to derive the level of risk the vessel poses (Risk Score).

**Impact factors** indicate the potential level of risk a vessel poses and can also be expressed as the 'severity/impact' axis in a risk matrix. An impact factor represents a threat to one of the four Risk Categories: Environment, Economy, Public Safety, Socio/Cultural Impacts (including Indigenous).

**Probability factors** are the likelihood the hazards factors can materialize and can be expressed as the 'probability' axis in a risk matrix. Condition factors describe the probability that the condition of the vessel can degrade, and therefore increase the likelihood of a hazard to one of the Risk Categories identified above materializing, and the timeframe it would likely materialize within.

**Importance factors** are modifiers that assign differential weighting to each of the Impact factors and Probability factors.

**Dilapidated vessel** means a vessel that meets any prescribed criteria and

- (a) is significantly degraded or dismantled; or

(b) is incapable of being used for safe navigation.

**Wreck** means

(a) a vessel, or part of a vessel, that is sunk, partially sunk, adrift, stranded or grounded, including on the shore;  
or

(b) equipment, stores, cargo or any other thing that is or was onboard a vessel and that is sunk, partially sunk,  
adrift, stranded or grounded, including on the shore.

## ***Appendix B - Literature Review***

# Appendix B – Literature Review

Vessels of Concern RAM

March 2019





## Appendix B - Literature Review

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## Appendix B - Literature Review

### 1.0 Appendix B - Literature Review

A literature review was conducted to gain an understanding of what is currently done in other jurisdictions to assess and manage VOC. The results of the literature review are summarized below and best practices gleaned are incorporated within the Risk Assessment Methodology.

#### 1.1. British Columbia

The British Columbia (BC) Ministry of Forests, Lands and Natural Resource Operations produced a guide to *Dealing with Problem Vessels and Structures in BC Waters* (n.d.) to provide a summary of the legal framework encompassing problem vessels and structures on BC Provincial Crown foreshore and Provincial Crown Land covered by water. The guide provides an overview of the responsible authority for different levels of government for different situations and points of contact. BC regulatory structure is slightly different than the rest of Canada. As such, the guidance document does not provide guidance for problem vessels in areas that are the responsibility of the federal government.

The guide provides contact information for the appropriate regulatory body (Transport Canada, BC Provincial Emergency Program, Receiver of Wreck, Joint Rescue Coordination Centre Victoria, BC Ministry of Forests, Lands and Natural Resource Operations) for the following concerns:

- Is the concern about a vessel or structure obstructing navigation?
- Is the concern about leaking harmful substances (i.e. oil)?
- Is the concern about sewage discharge?
- Is the concern about other types of pollution?
- Is the concern about objects that were once part of a wreck of stranded vessel and you want to salvage them?
- Is the concern about objects from a wrecked or problem vessel causing a public safety concern?
- Is the concern about a problem structure anchored or grounded on Crown land?
- Is the concern about a vessel anchored or moored for extended period on aquatic land owned by the Province?
- Is the problem related to local government bylaws (i.e. noise or, residential or commercial use)?

The BC Ministry of Forests, Lands and Natural Resource Operations produced another guide (2014) aimed toward technical staff. It recommends that it be determined whether a vessel is located in an area owned or administered by the federal government as the location of the vessel will inform who has legislative jurisdiction.

The document provides guidance on the following specific scenarios:

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- What can be done about non-Vessel structures that are anchored or moored, sunk or grounded in waters covering Provincial Crown Land?
- What can be done about problem Vessels that are anchored or moored in waters covering Provincial Aquatic Land?
- What can be done about Vessels and Structures that are impeding navigation?
- What can be done about Wreck or Vessels which are sunk, grounded or abandoned?
- What can be done in relation to Wreck, a Vessel or a floating or grounded Structure that is causing pollution?
- How can owners of Vessels and floating Structures responsibly dispose of their property?
- What responsibilities do persons carrying out activities on beaches have for protecting marine habitat?

The document recommends that for reporting a VOC the first contact should usually be port authority, harbour commission, or harbour management agency. Financial considerations and a collaborative approach between government levels and volunteers are important when dealing with problem vessels. The BC government has found that including volunteer effort with government resources has been effective in cleaning up debris and removing problem vessels. Governments should also consider the interest of all parties and how an action may affect a person's property and interests.

The Union of BC Municipalities created a Derelict Vessel Data Collection Sheet to provide Transport Canada with details on problem vessels, which is shown on **Figure 1**.

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### Derelict Vessel Inventory – Data Collection Sheet

Contact Information					
Name			Date (dd/mm/yy)		
Phone			Organization		
Email			Photos Taken (filename if digital)		

Vessel Information					
Vessel Type (Check applicable)	<input type="checkbox"/> Commercial <input type="checkbox"/> Pleasure <input type="checkbox"/> Engine <input type="checkbox"/> Fishing <input type="checkbox"/> Sailboat <input type="checkbox"/> Barge/Platform <input type="checkbox"/> Other (Describe)				
	Length (m/ft)		Beam (m/ft)		Vessel Name/Number
	Other Identifiers				
Vessel Material	<input type="checkbox"/> Wood <input type="checkbox"/> Steel/Metal <input type="checkbox"/> Fibreglass <input type="checkbox"/> Other (Describe):				
Condition (Check applicable)	<input type="checkbox"/> Floating <input type="checkbox"/> On Shore <input type="checkbox"/> Partially Sunk <input type="checkbox"/> Sunk <input type="checkbox"/> Secure <input type="checkbox"/> Unsecured <input type="checkbox"/> One Piece Floatable <input type="checkbox"/> One Piece not floatable <input type="checkbox"/> Multiple Pieces				

Location Information			
Waterway Name			Latitude (DMS)
Province			Longitude (DMS)
General Location			

Owner Information (If Known)	
Name:	Phone Number:
Address:	

Instructional Notes	
<p>1. It is encouraged to take as many pictures as possible to document the state of the vessel of concern. There should be pictures to show:</p> <ul style="list-style-type: none"> <li>a Location of vessel</li> <li>b Vessel – Multiple angles including the entire vessel as well as relevant close-ups</li> <li>c Close-up of contaminants (if present)</li> <li>d Close-up of vessel name and identification number (if present)</li> </ul>	<p>2. Please make sure that unless specifically known that the values for size and location are estimated.</p> <p>3. Describe the location of the vessel in as much detail as possible if the vessel is in a location that may be difficult to find again.</p> <p>4. Information on the vessel is essential for the identification of the owner but do NOT attempt to enter an abandoned or derelict vessel, unless you have followed all safety protocols.</p>

Figure 1: The Union of BC Municipalities created a Derelict Vessel Data Collection Sheet (2014)

## Appendix B - Literature Review

Issues Assessment (Please Rank Each Category)						
Criteria	1	2	3	4	5	Rank
Vessel Condition & Floatability	Vessel in good condition, floating with normal freeboard.	Vessel in neglected condition, sitting low in water but free floating	Vessel in poor condition, riding low in water but still floating.	Vessel has visible holes, is listing or upright may touch bottom at low tide or requires mechanical de-watering to remain afloat.	Vessel is not seaworthy; severely listing and/or sunk or aground	
Public Safety	Not accessible by the public.	Access by public is difficult.	Access to vessel is limited, and is a physical hazard	Public access is not limited and vessel has been scavenged creating a dangerous environment.		
How Secured	Tied securely to dock.	Moored or anchored securely.	Moored or anchored securely but lines in poor condition with heavy marine growth.	Not secured but grounded or beached.	Adrift or at imminent risk of becoming adrift.	
Navigation Concerns	Away from vessel traffic or beached	In area with light vessel traffic but away from navigation lanes	Encroaching navigation lanes of moderate traffic areas.	Encroaching on navigation lanes in high traffic areas such as large marinas or ports.	Obstructing passage in a restricted channel.	
Environmental Concerns	Known to be clean	Unlikely to contain fuel or other hazardous material.	Potentially carrying large amounts of fuel or hazardous materials	Multiple containers of unknown materials are visible on vessel. Condition of vessel make spill likely	Currently polluting into the marine environment	
					Total	

Figure 1 (continued): The Union of BC Municipalities created a Derelict Vessel Data Collection Sheet (2014)

## Appendix B - Literature Review

### 1.2. United States

The Waterways Management Subcommittee, of the U.S. National Association of State Boating Law Administrator's Governmental Affairs and Administration Committee (2009) describes best management practices (BMPs) on issues related to salvage insurance and effects of abandoned vessels.

The report provides 10 recommended BMPs to help resolve abandoned vessels:

1. Provide clear instructions to boaters on options for disposal of vessels as opposed to abandonment. Suggestions include donation, recycling, or dismantling.
2. Encourage boaters to dispose of vessels properly through financial incentives and disincentives.
3. Create a mechanism to title boats, so boats are documented and ownership can be more easily ascertained. The US Coast Guard Vessel Identification System (VIS) has 31 states and territories participating.
4. States understand agencies available to them, circumstances under which they will remove vessels, and any permits required to do so. Federal agencies will respond when pollution is imminent or vessel is a navigational hazard.
5. Create definitions for "abandoned boat", "derelict vessel", "vessel", and "ownership". Set time limits to distinguish abandoned from derelict vessels. Differentiating between the two categories may provide a more streamlined process for boats of no value.
6. Notifications to owner(s) should include information such as: description of the vessel and identifying numbers, location of vessel, rights to reclaim vessel within specific time limit, failure to claim will result in waiver of rights, and costs will be responsibility of owner.
7. If owner cannot be identified, a public notice to attempt to locate the owner of the abandoned/ or derelict boat should be completed.
8. An applicant for title of an abandoned boat should be provided with clear instructions on the process for registration of the boat.
9. Limits steps to allow transfer to an applicant that will take the vessel.
10. States should have a process in place to financially support the removal of abandoned boats and determining priority removals.

An example of data collected in the Sector Maryland – National Capital Region Abandoned Vessel Database, and the Abandoned/Derelict Vessel Reporting Form from the U.S. Coast Guard – Sector San Francisco Incident Management Division is shown below (**Figure 2**).

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U.S. Coast Guard Sector San Francisco Incident Management Division

Phone: (415) 399-3543

Fax: (415) 399-7302

### Abandoned/Derelict Vessel Reporting Form

INSTRUCTIONS: Fill out the following form to the best of your ability. If unknown, write unknown. Upon completion, forward by mail, email (above), or fax to IMD. For reporting after hours or in the event of an emergency, contact the Sector Command Center at (415)399-3547.

\*\*If you have pictures please contact Sector San Francisco Incident Management Division at the above number to discuss transmittal options. \*\*

**BE ADVISED OF THE FOLLOWING:** Derelict vessels not only pose a hazard to the environment but also pose many hazards to people. Please keep this in mind when gathering information and remain a safe distance from derelict vessels and **NEVER** go onboard.

#### Reporting Party Information

Date \_\_\_\_\_ Name \_\_\_\_\_

Phone Number \_\_\_\_\_ Organization \_\_\_\_\_

#### Vessel Information

Vessel Name \_\_\_\_\_ **Current Registration (Circle One):** Yes No

Registration Number \_\_\_\_\_ Registration Expiration \_\_\_\_\_

Other Identifying Numbers/Types \_\_\_\_\_

**Hull Type (Circle One):** Steel Wood Fiberglass Aluminum Cement Other \_\_\_\_\_

Length \_\_\_\_\_ Hull Color \_\_\_\_\_ Superstructure Color \_\_\_\_\_

Trim Color \_\_\_\_\_ **Vessel Type (Circle One):** Commercial Recreational Unknown

**Vessel Subtype (Circle One):** Cruising Sailing Fishing Passenger Barge Tug

General Condition of Vessel \_\_\_\_\_

Specific damaged areas of the vessel that can be readily seen. \_\_\_\_\_

**Vessel Is (Circle One):** Afloat Aground Tide Dependent **Hazard to Navigation? (Circle One):** Yes No

General Location and Approx. Water Depth \_\_\_\_\_

Lat/Long \_\_\_\_\_ County \_\_\_\_\_

#### Amplifying Information

**Is the vessel a pollution threat? (Circle One):** Yes No Unknown

Fuel Type \_\_\_\_\_ Total Fuel Capacity \_\_\_\_\_

Number of Tanks \_\_\_\_\_ Approx. Amount of Fuel \_\_\_\_\_

Figure 2: Abandoned/Derelict Vessel Reporting Form from the U.S. Coast Guard – Sector San Francisco Incident Management Division (2009)

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U.S. Coast Guard Sector San Francisco Incident Management Division  
Phone: (415) 399-3543 Fax: (415) 399-7302

Fuel Vent Location (if known) \_\_\_\_\_

Description and quantity of any HAZMAT onboard (Including Batteries): \_\_\_\_\_

\_\_\_\_\_

**Owner Information**

Last Known Registered Owner \_\_\_\_\_ Phone Number \_\_\_\_\_

Address \_\_\_\_\_

**Has the owner been contacted? (Circle One):** Yes No

Does the owner plan on taking action to remove/cleanup the vessel? If so, what? \_\_\_\_\_

\_\_\_\_\_

Additional point of Contact Information (Name, Phone Number, Address): \_\_\_\_\_

\_\_\_\_\_

Relationship of point of contact to owner: \_\_\_\_\_

**Additional Information**

Current or planned actions to cleanup/remove vessel by federal/state/local government: \_\_\_\_\_

\_\_\_\_\_

Any other information: \_\_\_\_\_

\_\_\_\_\_

Is this an update of a previous report? If so, what is the assigned derelict number of the vessel? \_\_\_\_\_

\_\_\_\_\_

Figure 2 (continued): Abandoned/Derelict Vessel Reporting Form from the U.S. Coast Guard – Sector San Francisco Incident Management Division (2009)

Another guidance document was developed by the National Response Team (NRT) (2014) of the U.S. Environmental Protection Agency to summarize laws and responsible authorities relevant to abandoned vessels and provide best practices to agencies for their management.

The document outlines how an initial assessment is an important component of responding to an abandoned vessel, as the information gathered will facilitate the responsible authority on potential actions to be taken. Information will vary significantly depending upon the type of vessel, however, the document highlights the following, presented in **Table 1**, as initial assessment information pieces.



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Criteria	
<b>Vessel Location</b>	<ul style="list-style-type: none"> <li>• Latitude/longitude</li> <li>• Accurate depth</li> <li>• General description of the area</li> <li>• Proximity to navigational channel</li> <li>• Proximity to infrastructure / port facilities</li> <li>• Within/outside state waters</li> <li>• If beached does it need securing</li> <li>• Navigation concerns or proximity to traffic areas</li> <li>• If accessible by public</li> <li>• Any potential risk to human health</li> </ul>
<b>Vessel Load / Threat of Pollution</b>	<ul style="list-style-type: none"> <li>• Capacity of fuel tanks</li> <li>• Hazardous Cargo (batteries, paint, hydraulic fluid in gear or stored, engine/generator crank case oil, propane tanks, and/or packaged cleaners)</li> </ul>
<b>Obstruction to Navigation</b>	<ul style="list-style-type: none"> <li>• Actual obstruction to navigation or potential hazard to navigation</li> </ul>
<b>Owner/Operator Information</b>	<ul style="list-style-type: none"> <li>• Owner, operator, lessee</li> <li>• Contact details</li> <li>• Insurance details</li> </ul>
<b>Physical Construction and Condition</b>	<ul style="list-style-type: none"> <li>• Hull material (wood, fiberglass, steel, or composite)</li> <li>• Hull condition and its stability and structural integrity</li> <li>• Overall safety implications for surveys and feasibility of raising/removing</li> </ul>
<b>Potential Link to Illegal Activities</b>	<ul style="list-style-type: none"> <li>• If the vessel is or has potential to become a haven for illegal activity</li> </ul>
<b>Sensitive Habitat or Protected Resources</b>	<ul style="list-style-type: none"> <li>• Coral, sea grass, sensitive marine habitats</li> <li>• Irreplaceable historical and cultural marine resources</li> <li>• Antifouling paints</li> <li>• Invasive species</li> <li>• Nutrient enrichment from rusting steel</li> <li>• Dispersion of fishing gear and/or marine debris</li> </ul>
<b>Potential Historic Preservation Status</b>	<ul style="list-style-type: none"> <li>• Requirements for vessels over 50 years old</li> <li>• Historic properties or gravesite status</li> </ul>

Table 1: Initial Assessment Pieces (NRT, 2014)

Establishing if a vessel is potentially polluting or posing a hazard to navigation is an important criteria as funding is typically available for vessels in these categories. The U.S. Army Corps of Engineers' (USACE) provides specific criteria for determining if an abandoned vessel is a hazard to navigation. The criteria are:

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- Location of the obstruction in relation to the navigable channel and other navigational traffic patterns.
- Navigational difficulty in the vicinity of the obstruction.
- Clearance or depth of water over the obstruction, fluctuation of water level, and other hydraulic characteristics in the vicinity.
- Type and density of commercial and recreational vessel traffic, or other marine activity, in the vicinity of the obstruction.
- Physical characteristics of the obstruction, including cargo, if any.
- Possible movement of the obstruction.
- Location of the obstruction in relation to existing aids to navigation.
- Prevailing and historical weather conditions.
- Length of time the obstruction has been in existence.
- History of vessel accidents involving the obstruction.

The document provides an example abandoned vessel program development from the State of Washington and the following general recommendations:

- Central reporting entity and database accessible by all government departments
- Warning system for safe navigation and environmental protection with communication between local and state authorities
- Vessel registration or process for identifying documented vessel owner
- Adoption of standard criteria for hazards to navigation and environmental concerns
- Develop programs to incentivise owner disposal over abandonment
- Set standards for civil penalties for vessel abandonment
- Authority should be given to local marinas or harbour masters when possible to facilitate removal and disposal

The report *Risk Assessment for Potentially Polluting Wrecks in U.S. Waters (NOAA, 2013)* provides an assessment of the oil pollution risk from potentially polluting wrecks in U.S. waters. The risk assessment process was developed to support U.S. Coast Guard Federal On-Scene (FOSCs), and Local Area Committees in their decision making.

There are approximately 20,000 shipwrecks in U.S waters with only a fraction that are likely to contain oil. NOAA maintains Resources and Undersea Threats (RUST) for shipwrecks, dumpsites, navigational obstructions, underwater archaeological sites, and other underwater cultural resources. The risk assessment focused on wrecks most likely to contain harmful quantities of oil and included a modeling of potential oil spills from priority wrecks to identify ecological and socio-economic resources at risk. This resulted in the creation of the Remediation of Underwater Legacy Environmental Threats (RULET) database for a subset of wrecks in RUST with highest potential to cause pollution

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NOAA used a tiered screening approach due to the volume (20,000) shipwrecks in the RUST database. Initial screening from readily available information to determine vessels with most likely to have risks of oil pollution. Initial screening factors were focused on:

- Vessel age
- Vessel location
- Vessel construction
- Propulsion type
- Vessel type
- Vessel Size

A ship's age can be used as an indication of both its propulsion (fuel) type and construction. First oil-fired ships were constructed in the early 1890s, and as part of the initial screening NOAA excluded vessels built prior to 1891. The NOAA study boundary included only wrecks within the U.S. EEZ, including the U.S. portions of the Great Lakes. Only vessels built of durable materials (e.g., steel, iron, and concrete) were included past the initial screening, and all sailing vessels and coal-fired vessels were excluded. Tank vessels (oil tankers and tank barges) are considered the greatest risk for oil pollution, given some vessels are designed to transport large amounts of oil as cargo or fuel and were all included in the RULET database. All non-tank vessels less than 200 feet in length or less than 1,000 gross tons were not included past the initial screening.

A secondary wreck screening process was completed to determine potential risk based on the structural integrity of the wrecks. Archival and historic research to determine physical integrity, potential cargo and fuel onboard, and vessel casualty information. Information on how much oil a vessel had potentially been carrying and the likelihood it was lost to due to structural integrity of the vessel and/or casualty type impacted the assessed risk.

NOAA assumed that every wreck not screened out still contained oil. The maximum amount of oil that a ship could carry was estimated, and this was used for oil spill modeling. Regression models were developed based on a series of release volumes to assess risks for smaller volume releases. For consequence analysis both a Worst Case Discharge (total loss) and Most Probable Discharge (10% loss of the Worst Case Discharge). A Worst Case Discharge provides a conservative benchmark, while a 10% release provides context when comparing against other potential risks.

Oil fate and effects modeling was completed using RPS ASA's Spill Impact Model Application Package (SIMAP) to model potential consequences from the priority wreck. Stochastic modeling was used to estimate areas of water surface, lengths of shoreline, and volumes of water exposed above effects thresholds.

While 107 wrecks were identified in the screening analysis, risks assessments were only completed for 87 vessels as 20 vessels with Low Worst Case and Most Probable scores were dropped. For analysis, 21

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clusters of wrecks were grouped based on their proximity to each other. Model inputs included in the analysis included:

- Winds
- Currents
- Temperature and Salinity
- Horizontal and vertical diffusion coefficients
- Habitats and Depths
- Oil Types – grouped into three general categories
  - Light fuel (e.g., marine diesel, fuel oil #2, fuel oil #4)
  - Heavy fuel (e.g., Bunker C, Navy fuel oil)
  - Crude oil
- Release volumes – depth 2 to 3 m above seafloor
  - Worst Case Discharge (WCD) – 100%
  - Large release – 50% of the WCD
  - Most Probable Discharge – 10% of the WCD
  - Episodic release of 1% of the WCD
  - Chronic release of 0.1% of the WCD

The calculation of risk was determined by the product of probability and consequences. This included, vessel risk, oiling risk, and ecological and socio-economic risks. The criteria used for ecological and socio-economic risks were those presented in **Table 2**.

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### Criteria

<b>Ecological Resources at Risk (Eco RAR):</b>	<ul style="list-style-type: none"> <li>• Seabirds</li> <li>• Pelagic Birds, Waterfowl, and Driving Birds</li> <li>• Shorebirds and Colonial Nesting Birds</li> <li>• Sea Turtles</li> <li>• Marine Mammals</li> <li>• Fish and Invertebrates</li> <li>• Benthic Habitats</li> <li>• Shore Communities/ Tourist Beaches</li> <li>• Ports/Shipping Lanes</li> <li>• Tribal Lands</li> <li>• State Parks</li> </ul>
<b>Socio-economic Resources at Risk (SRAR):</b>	<ul style="list-style-type: none"> <li>• Subsistence Fishing</li> <li>• Commercial Fishing</li> <li>• Federal Protected Areas, National Wildlife Refuges, National Marine Sanctuaries, National Parks, National Seashores, National Lakeshores</li> <li>• Power Plant Intakes</li> <li>• Wind Farms</li> <li>• Offshore Oil Exploration and Production</li> </ul>

Table 2: Criteria used for Ecological and Socio-economic Risks (NOAA, 2013)

The risk assessment process evaluated impacts to ecological and socio-economic resources in the water column, on the water surface, and on the shoreline. For each of these categories the risk was classified with regard to the probability of oiling and the degree of oiling. A three-point scale of Low, Medium, and High were used to categorize the levels of probability and impact. Each vessel had three scores for ecological impacts and three scores for socio-economic impacts. Six component scores were added to the score generated from analysis of pollution potential factors, along with data quality. An example of the RULET scoring is provided in **Figure 3**, as well as a potential decision flow chart in **Figure 4** to determine whether to monitor, assess, and/or remove oil from a potentially polluting wreck.

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Vessel Risk Factors		Data Quality Score	Comments	Risk Score	
Pollution Potential Factors	A1 Oil Volume (total bbl)	Medium	Maximum of 93 000 bbl, not reported to be leaking	Med	
	A2 Oil Type	High	Cargo is crude oil, a Group III oil type		
	B Wreck Clearance	High	Vessel not reported as cleared		
	C1 Burning of the Ship	High	Significant fire reported		
	C2 Oil on Water	High	Oil was reported on the water; amount is not known		
	D1 Nature of Casualty	High	Multiple torpedo detonations, explosion		
	D2 Structural Breakup	High	Vessel remains in one contiguous piece		
Archaeological Assessment	Archaeological Assessment	High	Detailed sinking records and site reports of this ship exist, assessment is believed to be very accurate	Not Scored	
Operational Factors	Wreck Orientation	High	Inverted (turtled)	Not Scored	
	Depth	High	90 feet		
	Visual or Remote Sensing Confirmation of Site Condition	High	Location has been surveyed		
	Other Hazardous Materials Onboard	High	No		
	Munitions Onboard	High	Munitions for onboard weapons		
	Gravesite (Civilian/Military)	High	Yes		
	Historical Protection Eligibility (NHPA/SMCA)	High	NHPA and possibly SMCA		
				WCD	Most Probable
Ecological Resources	3A Water Column Resources	High	Nearshore habitats which are important spawning areas at greatest risk of impact	Med	Med
	3B Water Surface Resources	High	Slicks could cover large areas with abundant wintering waterfowl, sea turtles concentrated in Sargassum mats where oil also tends to concentrate, and spawning habitat for many fish/shellfish	High	Med
	3C Shore Resources	High	Shoreline resources include wetlands which are difficult to clean and under long-term decline, large bird nesting colonies, turtle nesting beaches, nursery areas for many fish and shellfish, and wintering habitat for listed bird species	High	Med
Socio-Economic Resources	4A Water Column Resources	High	Moderate water column impact in important fishing grounds	Low	Low
	4B Water Surface Resources	High	Relatively large impact in important shipping lanes and fishing areas	High	Med
	4C Shore Resources	High	Moderate shoreline oiling would occur in areas with important resources	Med	Med
Summary Risk Scores				Med	13

Figure 3: Summary Scoring of RULET Wreck (NOAA, 2013)

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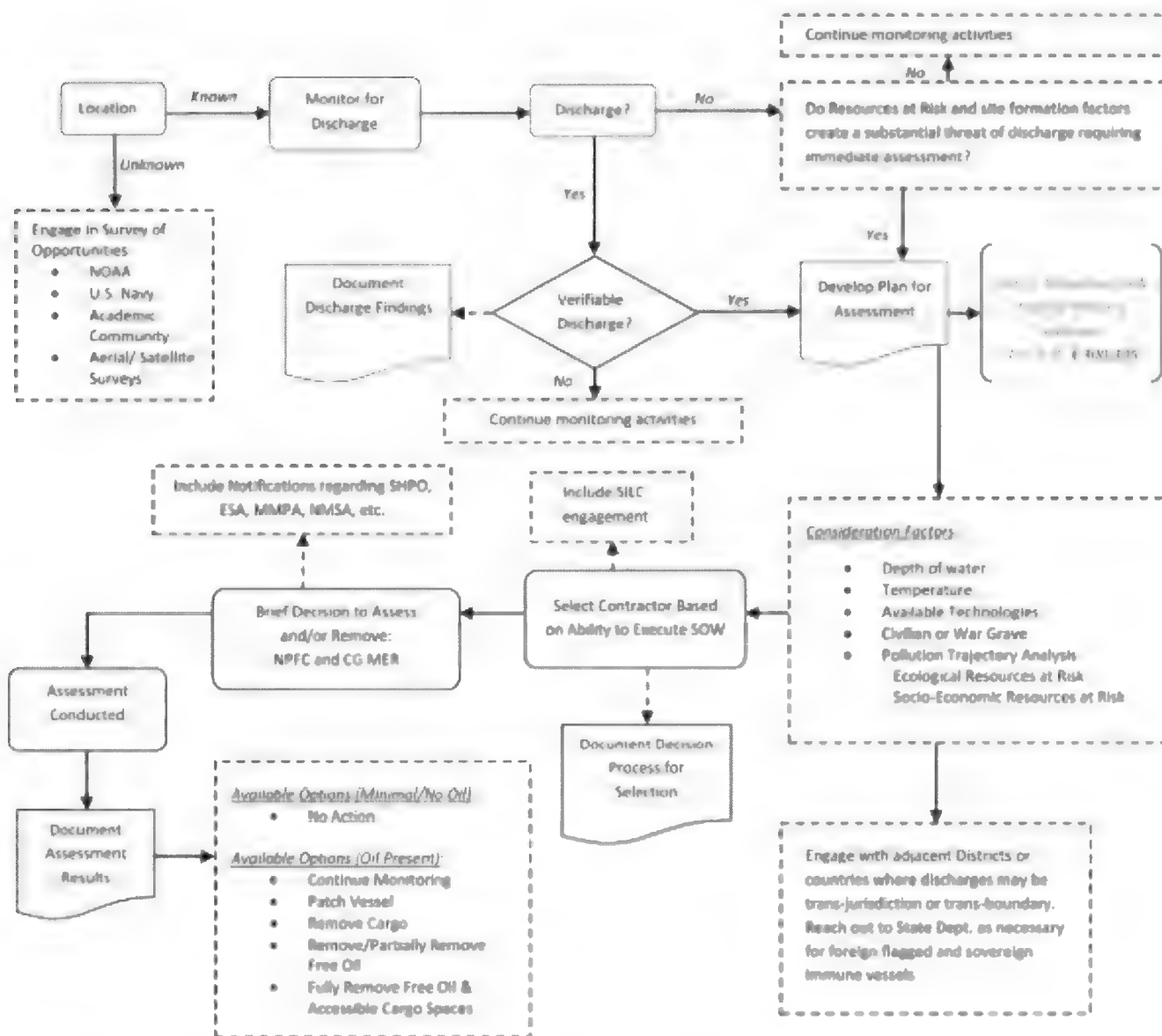


Figure 4: Decisional Flow Chart for Wrecks in U.S. Coast Guard Districts (NOAA, 2013)

NOAA identified a number of risk assessment projects outside the U.S. and compared the different risk assessment methodologies and projects with the NOAA RULET effort. The other projects include the South Pacific Project, the U.K. Maritime Coastguard Agency (MCA) Potentially Polluting Wrecks Database, the Scandinavian risk assessment project, and the Development of European Guidelines for Potentially Polluting Shipwrecks (DEEPP), and the National Maritime Research Institute (Japan) Risk Assessment Model. The summary and comparison completed by NOAA are shown in **Figure 5** and **Figure 6**.

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Project Name or Location	Authorities Involved	General Approach
<b>Scandinavia (Sweden, Denmark)</b>	Swedish Maritime Administration National Environmental Research Institute (Denmark) Chalmers Univ. of Technology Alliance for Global Sustainability Swedish Coast Guard Swedish Navy Swedish Defense Research Agency Swedish National Heritage Board	<ul style="list-style-type: none"> <li>• Analysis of legal situation of wrecks</li> <li>• Case study on SS <i>Skytteren</i></li> <li>• Analysis of eco-toxicology of long-term leakage</li> <li>• Wreck database</li> <li>• Archaeological/engineering library research on wrecks</li> <li>• Risk model with five-point classes of probabilities of leakage and five ranks of consequences (human, economic, and ecological)</li> <li>• Oil trajectory modeling</li> <li>• International cooperation on assessments</li> </ul>
<b>DEEPP Mediterranean (France, Italy)</b>	European Commission ICRAM CEDRE Italian Navy (Mandragrafico) French Navy (SHOM)	<ul style="list-style-type: none"> <li>• Wreck database (194 known wrecks) in the Mediterranean</li> <li>• Archaeological/engineering library research on wrecks</li> <li>• Sea bottom exploration</li> <li>• ROV investigation of selected wrecks</li> <li>• Risk matrix with hazards by oil type</li> <li>• International cooperation on assessments</li> </ul>
<b>Transport Canada (Eastern Canada)</b>	Transport Canada Canadian Coast Guard Provincial Authorities	<ul style="list-style-type: none"> <li>• Charting of 1,000s of wrecks off eastern Canada coast</li> <li>• Aerial surveillance for mystery spills</li> <li>• Establishment of contingency plans for spills, removal</li> </ul>
<b>Kystverket Norway</b>	Norwegian Coastal Administration (Kystverket)	<ul style="list-style-type: none"> <li>• Wreck database of ships sunk after 1914 over 50 m and over 100 tonnes (over 2,300 entries)</li> <li>• ROV survey on all wrecks classified as high risk (30 wrecks containing 100-300 tonnes oil)</li> <li>• Risk assessment by position, wreck type, fuel</li> <li>• Study on pollutants other than oil</li> </ul>
<b>SPREP (South Pacific)</b>	Pacific Ocean Pollution Prevention Programme (PACPOL) International Maritime Organization (IMO) Canada-South Pacific Ocean Development Secretariat of the Pacific Regional Environment Programme (SPREP)	<ul style="list-style-type: none"> <li>• Extensive mapping and identification of wrecks (particularly World War II-related)</li> <li>• Comprehensive database (3,000 wrecks)</li> <li>• Risk analysis (4% selected for further study)</li> <li>• International cooperation identifying wrecks</li> </ul>
<b>U.K. MCA (United Kingdom)</b>	Maritime Coastguard Agency Ministry of Defense	<ul style="list-style-type: none"> <li>• Wreck database (25,000 records)</li> <li>• Archaeological/engineering library research on wrecks</li> <li>• Risk analysis of munitions, spills</li> <li>• Risk matrix of pollution/safety severity and likelihood</li> </ul>
<b>National Maritime Research Institute (Japan)</b>	National Maritime Research Institute Tokyo University of Marine Science and Technology	<ul style="list-style-type: none"> <li>• Development of environmental risk assessment tool</li> <li>• Development of technologies to mitigate oil discharges</li> </ul>

Figure 5: Summary of international risk assessment projects by NOAA (2013).



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Project	Database	Trajectory Modeling	Engineering and Archaeological Assessment	Risk Model or Matrix	Mapping	Other Hazards	Full Risk Assessment
<b>NOAA 2012 RULET</b>	Extensive data on vessels, potential impacts to resources at risk	Trajectory, fate, and effects modeling	Comprehensive	Yes	Yes	Limited data on munitions, chemicals	Yes, for 87 priority wrecks
<b>Scandinavia</b>	Extensive data on vessels	Some trajectory modeling	Limited	Yes	Yes	Limited data on other pollutants	One wreck; others in process
<b>DEEPP</b>	Location, type, size, owner, age	None	Limited (some surveys)	Yes	Yes	MARPOL chemicals	None
<b>Transport Canada</b>	Location, type, size, owner, age	None	No	None	Yes	None	None
<b>Kystverket</b>	Extensive data on vessels	None	Limited	None	Yes	Chemicals	Planned
<b>SPREP</b>	Location, type, size, owner, age	None	No	None	Yes	None	None
<b>U.K. MCA</b>	Extensive data on vessels	None	Limited	Yes	Yes	Munitions Chemicals	Planned
<b>NMRI, Japan</b>	No database	Trajectory and fate modeling planned	No	Yes	No	No	None

Figure 6: Comparison of risk assessment approaches by NOAA (2013).

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### 1.3. International

The paper *Potentially Polluting Wrecks in Marine Waters* (2005), prepared for the 2005 International Oil Spill Conference, was written to describe the state of potentially polluting wrecks. The paper focused on vessels pollution by petroleum products at the time and made recommendations for next steps. Chapter V of the paper describes a methodology for assessing risks of potentially polluting wrecks and potential steps to mitigate their impact, and prioritize remedial activities. A generalized methodology, modified from the methodology propped by the South Pacific Regional Environment Programme (SPREP, 2002) for assessing risk posed by sunken shipwrecks is outlined as follows in **Table 3**.

#### Information Gathering

- **Develop an accurate sunken vessel database**
- **Identify the ownership of individual wrecks and the jurisdictional responsible authority for each vessel**
- **Confirm and map locations of sunken vessels**
- **Confirm the identity of vessels including cargo quantities and types**
- **Determine if there are previous reports of oil spills in the area and they are from the vessels**
- **Collect information on vessel history prior to sinking**

#### Implications/Consequences

- **Assess likely scenarios for impact of any released oil (release scenarios, spill trajectory and oil fate modeling)**
- **Determine the ecological and socio-economic resources at risk in the area and current impacts**
- **Estimate the ecologically important sea/coastal/land uses of the region**
- **Document the physio-ecological character of the surrounding shorelines**
- **Determine and assess the impacts of an oil spill from the wreck on wildlife and fisheries in the region**
- **Determine possible consequences of oil release scenarios (environmental sensitivities, economic risks, subsistence or recreational fishing)**

#### Assessment of Risk Priority/Actions

- **Select priority sites or wrecks to employ mitigation strategies and oil cargo and/or wreck salvage**
- **Determine which sites/wrecks require regular pollution surveillance or monitoring by local or remote techniques**
- **Carry out site investigations, inspections, and assessments of vessel integrity and tank sounds where possible**
- **Assess the accessibility issues related to the wreck and potential oil cargo off-loading strategies**
- **Determine contingency arrangements for offloading of oil cargos including spill containment, oil recovery, and waste disposal options**
- **Assess any physical or ecological constraints on salvage activities or cleanup operations**
- **Provide an overall recommendation on any necessary actions related to the remaining oil**

Table 3: Generalized Methodology (SPREP, 2002) Table 4: Generalized Methodology (SPREP, 2002)

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The paper provides risk assessment criteria matrices rating risk for each criteria as high, medium, or low risk. These criteria are grouped into three categories described as site information, environmental criteria, and socio-economic criteria. These tables are provided as **Figure 7**. The paper recommends that vessels categorized as high risk require action or mitigation, medium risk require monitoring and reassessment if conditions change, and low risk require no action.

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<i>Site Assessment Criteria</i>			
<b>Risk Assessment Criteria and Questions</b>	<b>High Risk</b>	<b>Medium Risk</b>	<b>Low Risk</b>
What is the size, type, and construction of the sunken vessel?	>10000 tonnes	1000-10000 tonnes	<1000 tonnes
What is the likely quantity of oil on board?	High; >1000 tonnes	Moderate; 100-1000 tonnes	Low; <100 tonnes
How accessible is the wreck to shore?	Nearshore or Lagoonal	Offshore but accessible	Open sea
How deep is the water where the wreck rests?	Access by conventional SCUBA	At limit of diving capability	Deep water Submersible access only
Has the wreck a history of previous oil releases?	Documented history of oil leaks	Occasional oil leaks or not known	None
What oil types are contained in the wreck? Are they persistent oils once spilt at sea?	Very persistent oil	Medium grade oils	Non-persistent oil
Is the wreck subject to severe weather events, such as storms, monsoons, hurricanes, typhoons?	High degree of severe weather possible	Moderate degree of severe weather possible	Low degree of severe weather possible
What is the stability of the seabed and what are the sediment effects on the wreck movement and integrity?	Unstable and or high degree of movement	Relatively stable or not known	Known to be a stable seabed
What is condition of the wreck, degree of deterioration, and its fragility to natural disturbance effects?	Significant deterioration	Moderate deterioration	Mostly intact
Is the wreck subject to high level of hydrodynamic forces on the seabed?	High level of sub-sea currents	Medium level of hydrodynamic forces	Low level of currents and driving forces

Figure 7: Risk Assessment Criteria Matrices (Michel, et al., 2005)

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<i>Environmental Assessment Criteria</i>			
<b>Risk Assessment Criteria and Questions</b>	<b>High Risk</b>	<b>Medium Risk</b>	<b>Low Risk</b>
Are there areas of high environmental sensitivity in the region? Consider distribution of sensitive habitats such as marshes, mangroves, seagrasses, coral reefs, mud flats, and kelp beds.	High level of environmental sensitivity	Medium level of environmental sensitivity	Low level of environmental sensitivity
Does spill trajectory modeling indicates significant environmental resources at risk from oil releases?	High probability of impact	Moderate probability of impact	Low probability of impact
How unique, rare or diverse is the ecology of the area likely to be affected?	High	Medium	Low
Are rare or endangered wildlife located within the region or potential spill impact zones?	High level of protected species in region	Low level of protected species in impact zone	No protected species in impact zone
What sensitive wildlife species are at risk? Consider the diversity, number, locations, and seasonality.	High number and diversity	Medium number and diversity	Low number and diversity
Are there routes for transitory species, such as migratory birds and marine mammals?	High abundance	Occasional	None
What is the preservation or protection status of the area at risk? Considerations include: marine park, wilderness, world heritage, and conservation status?	High level of protection and preservation	Moderate level of protection and preservation	Low or no level of protection and preservation
Are there any historical, cultural or archaeological resources in the area at risk, including war graves?	Significant resources and high value	Moderate level of resources	Low level or not present
Does the area at risk have subsistence fishing, traditional hunting gathering or fish traps in the wreck area?	High degree of subsistence living in region	Medium level of dependency on subsistence	Low level or no dependency on subsistence
What is the extent of scientific, educational, or research interest in the area at risk?	High degree of interest	Occasional interest	Low or no interest

Figure 7 (continued): Risk Assessment Criteria Matrices (Michel, et al., 2005)

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<i>Economic Assessment Criteria</i>			
<b>Risk Assessment Criteria and Questions</b>	<b>High Risk</b>	<b>Medium Risk</b>	<b>Low Risk</b>
Are licensed commercial fisheries, fish farms, aquaculture, pearl farming etc in the area at risk?	High level of economic value	Moderate level of economic value	Low level of economic value
What other significant industrial uses, economic resources or important uses of the sea are present in the area at risk (e.g., water intakes, aquaria, salt-pans)?	High level of economic use and dependency	Medium level of economic use and dependency	Low level of economic use and dependency
What important recreational or tourism activities are carried out in the area at risk (e.g., sport fishing, diving, snorkeling, boating, sightseeing, surfing, coastal recreational use)?	High level and/or high degree of economic value	Medium level and/or moderate degree of economic value	Low level and/or low degree of economic value
What level of marine use occurs within the area of the wreck?	High degree and range of marine uses	Medium degree and range of marine uses	Low degree and range of marine uses
Is the region used as a marine transport corridor?	High degree of use	Medium level of use	Low level of use
Does the wreck contain sufficient quantities of unexploded ordnances (UXOs) or other dangerous goods (DGs) that would pose a safety hazard or require exclusions zones near the wreck?	High quantities of UXOs and/or DGs known on wreck	Moderate or unknown quantities of UXOs and/or DGs on wreck	Low or no UXOs DGs on wreck

Figure 7 (continued): Risk Assessment Criteria Matrices (Michel, et al., 2005)

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### 1.3.1. Europe

The Development of *European Guidelines for Potentially Polluting Shipwrecks* (DEEPP) project report (Alcar et al., 2007) was developed to provide National European administrations with guidelines to face environmental threats from potentially polluting wrecks. The report describes the creation of the DEEP database and the risk assessment methodology applied to categorize the potentially polluting wrecks. Attributes collected for each vessel in the database included:

- Name
- Type of wreck
- Description of wreck
- Cause of shipwreck
- Shipwreck date
- Gross tonnage, length, and width
- Flag state, building date, shipyard
- Territorial water
- Longitude and Latitude
- Localisation Accuracy
- Distance from coast and sensitive areas
- Depth and nature of sea bottom
- Bunker nature and volume
- High and low estimates for bunker volume remaining
- Engine power
- Hold capacity
- Nature of cargo and cargo class
- Risk description
- Exacerbating factor (related to wreckage year)
- Spill description
- Wreck status
- Diffusion wright

After developing the DEEPP Database a risk assessment was completed to categorize the vessels. The methodology focused on four parameters:

- Pollutant Volume
- Distance to a coast or a sensitive area when available
- Nature of the product involved: fuel or cargo
- Exacerbating factor: age of the wreck

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The four volume classes of pollutant volumes were determined to be:

- 1 – <100 m<sup>3</sup> (lost containers, small coastal tankers)
- 2 – 100-500 m<sup>3</sup> (small chemical tankers, barges, coastal oil tankers, container ships)
- 3 – 500-2500 m<sup>3</sup> (coastal oil tankers, barges, chemical tankers, container ships)
- 4 – >2500 m<sup>3</sup> (Chemical tankers, oil tankers)

The four classes of distances from the coast were determined to be:

- 1 – < 1 mile
- 2 – 1 mile to <10 miles
- 3 – 10 miles to <50 miles
- 4 – >50 miles

Floating pollutants were grouped into the four categories of light fractions, intermediate fuel oils, light crude, and heavy/medium crude. There were 11 risk factors calculated by dividing the volume class by the distance class. Each pollutant category was assigned an impact level based on a risk matrix developed for each risk factor. The risk assessment matrix is shown in **Figure 8**.

The impact levels developed were:

- Serious – potentially very severe effects and should receive immediate response.
- Moderate – potential impacts that should be monitored. This was further subdivided into minor to moderate and moderate to serious.
- Minor – limited potential for impacts and response may not be cost-effective.



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Risk FactorF				
4	serious	serious	serious	serious
3	serious	serious	serious	serious
2	serious	serious	serious	serious
3/2	serious	serious	serious	serious
4/3	Moderate to serious	serious	serious	serious
1	Moderate to serious	Moderate to serious	serious	serious
3/4	moderate	moderate	serious	serious
2/3	moderate	moderate	Moderate to serious	serious
1/2	Minor to moderate	moderate	Moderate to serious	Moderate to serious
1/3	minor	Minor to moderate	moderate	Moderate to serious
1/4	minor	minor	Minor to moderate	moderate
Hydrocarbons: fuels and cargo	Gasoline	Fuel Oil Diesel Kérosene	Light crude oils	Heavy/Medium crude oils  HFO/IFO
Liquid Chemical transported in bulk Marpol Classification	OS	Z	Y	X

Figure 8: Risk Assessment Matrix (Alcar, et al., 2007)

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